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Volume 2 Issue 2

February 2000

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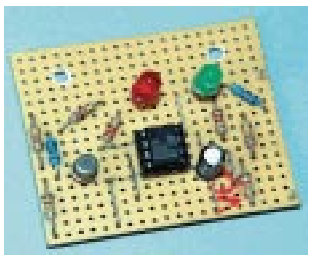

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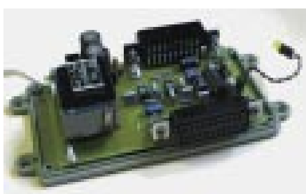

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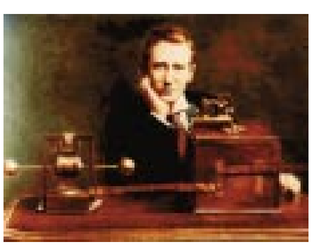

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Editorial

A HIGH PRICE

Is overcharging restricting UK development of electronic trading? Comments in Alan Winstanley's *Net Work* column this month show just how expensive use of the Internet is in the UK in comparison with the USA. What is also obvious to us (we maintain Web sites both in the UK and in the USA) is that the cost of UK web space is far higher than that in the USA. The higher call rates, as discussed in Net Work, may not seem significant, but what really made Internet use and services take off here in the USA was the introduction of virtually free access for all.

Anyone who has seen any American TV recently cannot fail to realise just how big Internet use is. In addition to a number of TV programs aimed at web surfers, buying online and so forth, almost every advert now carries a URL (in fact many adverts are only advertising Web sites). Whilst there are a few such adverts in the UK, it is obvious that the UK is way behind what is happening on our side of the pond.

Development in the USA has been so rapid and so all encompassing that the FCC are now taking steps to ensure that a situation of "haves" and "have-nots" does not arise. Their worry is that those with web access – the vast majority of the US population in one way or another – will have the power of the knowledge resource behind them, whilst a poorer section of the community may be starved of such access and find it harder and harder to stay in touch with today's modern world, thus restricting the job opportunities open to this group. The FCC are forcing high tech companies to pay for systems that give access to all by placing computers into schools and communities that cannot afford them themselves.

We can certainly see a (not-so-distant) future where access to the Web, email, and so forth will be essential for virtually all businesses and, of course, the ability to use the technology is already essential in many jobs. The problem with technology is that it moves at an ever increasing pace – just look at how far we have come from nowhere in the last 100 years or so. It is essential for the UK and other countries around the world to keep up with electronic trading worldwide.

A HIGH PRICE

Speaking of the last 100 years, his month sees the start of our "Technology Timelines" series of articles, which review how we arrived where we are today (and where we look like ending up tomorrow). This first installment commences by considering the state of the art as the world was poised to enter the 20th Century.

Clive Maxfield & Alvin Brown

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Next Month

EPE ICEBREAKER

Real time PIC In-Circuit Emulator, Programmer, Debugger, and Development System

Icebreaker uses the very latest features of the PIC16F877 range of high performance RISK microcontrollers. These advanced chips communicate via a PC serial port and allow code to be programmed, run, and debugged.

Working in a Windows environment with Microchip's MPLAB software, programs can be written, loaded and tested by 'single stepping' or running at full speed in their final application board.

In-Circuit Emulation means that as a program is run or stepped through, the I/O ports on the chip respond immediately – reading and driving any external hardware.

Commands include: Reset; Halt on external pulse; Set single breakpoint; Examine and change registers, program, and EEPROM; Load program from .HEX file, Single step – with display of Status bits, W register, Program Counter, and selected 'Watch window' registers.

The development board has switches, LEDs, connectors for add-on LCD and 7-segment LED displays, a socket for a plug top power supply, voltage regulator, 9-pin serial connector, "patch areas", and space for a small "breadboard".

For beginners and advanced users – from simple programs such as those from the EPE PIC Tutorial (code written for the PIC16F84 or 'C84 also runs on the '877), to large complicated programs using the many special features of the PIC chips.

AUTOMATIC TRAIN SIGNAL

This very simple starter project is a two-color (red/green) signal for a model railway. It uses a simple form of automatic operation, and if you stop the train in front of the signal it automatically switches from "green" to "red". When the train is restarted the signal automatically switches to "green" again. To an onlooker it appears as though the signal is changing color and the train is responding to the change. In reality, the train and the signal are both responding to changes in the track voltage.

PARKING WARNING SYSTEM

An unusual system which bounces a coded infrared beam off the car in order to detect its position. When the preset sensed distance has been reached, a buzzer and LEDs are operated to warn the driver it's time to stop.

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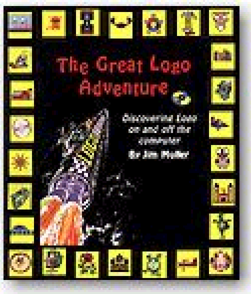
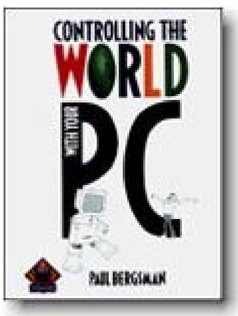
A selection of ELECTRONIC Books for Hobbyist and Students



The Great Logo Adventure

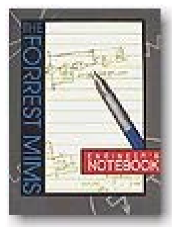
A cartoon-illustrated, family activity book for exploring animation, graphics, math, geometry, ... Ideal for teaching programming concepts to young people of all ages.
FREE CD-ROM (for PCs and Macs) contains Logo software plus lots of other stuff.

More details are available on the EPE Online web site



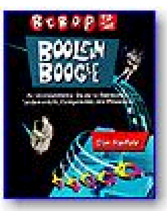
Controlling the World With Your PC

Connect your MS-DOS/Windows PC to the real world with this best-selling book!
Comes with all software (executable files plus C, Basic, and Pascal



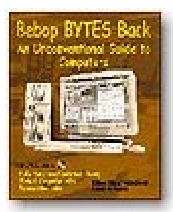
Forrest Mims Engineer's Notebook

This revised edition includes hundreds of useful circuits designed and built by Forrest using commonly available integrated circuits and other components.



Bebop to the Boolean Boogie (An Unconventional Guide to Electronics)

This in-depth, highly readable, up to the minute guide shows you how electronic devices work and how they're made -- the only electronics book where you can learn about musical socks and the best time of the day to eat smoked fish!



Bebop BYTES Back (An Unconventional Guide to Computers)

This follow-on to *Bebop to the Boolean Boogie* is a multimedia extravaganza of information about how computers work.
FREE CD ROM contains the *Beboputer Computer Simulator*, along with over 200 megabytes of mega-cool multimedia.

Visit the EPE Online Store at www.epemag.com and place your order today!

Constructional Project

EASY-TYPIST TAPE CONTROLL

by ANDY FLIND

Improve keyboard skills, audio/visual presentations, and script prompter

This little project was devised to speed the task of typing text into a computer, though it will probably find plenty of other uses. It plays recorded speech a few words at a time, waiting for a prompt before continuing. This allows people who cannot type without looking at the screen or keyboard to type rapidly and continuously since it removes the need to refer frequently to the text being typed, which in the case of handwriting can be extremely tedious.

There are, of course, other ways to enter text into a computer. Printed matter of suitable quality can be scanned and read with optical character recognition, but this assumes that a reasonably powerful computer is available together with the software and a scanner, and it cannot be used with handwriting.

Voice recognition software is now available but this requires serious computing power and still has an error rate which many people find unacceptable. Also, it is difficult to see how this kind of software will ever be able to deal with words which sound the same, such as "to", "too" and "two" in the foreseeable future.

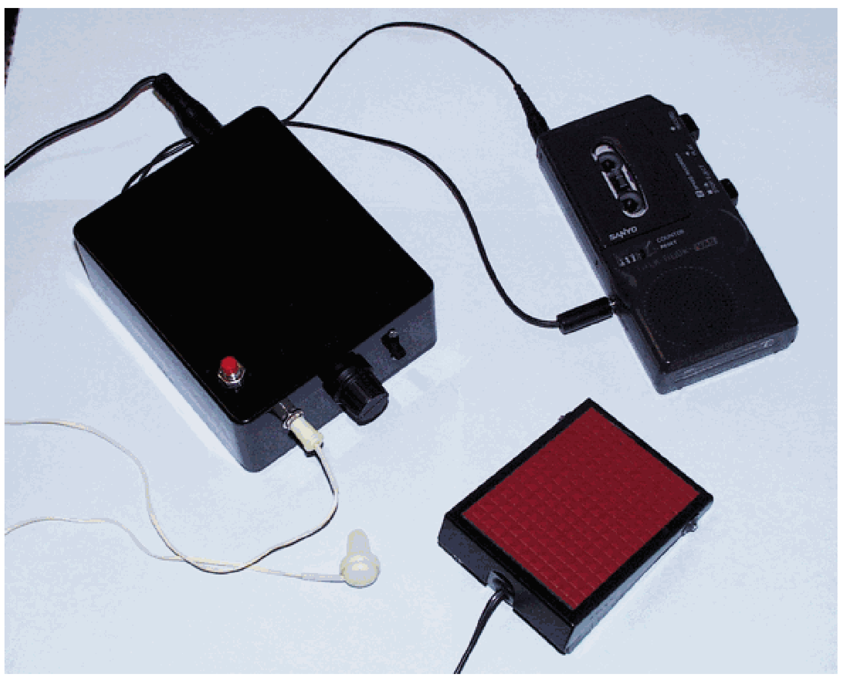
PAUSE FOR THOUGHT

The time-honored way to do the job is to dictate the text into a tape recorder and play it back whilst typing, but this normally requires a "transcribing machine" as used by audio typists. The difference between these and ordinary tape players is that they can be started and stopped almost instantly and can "backspace" to play the last few words again, usually with a footswitch control. They are expensive though, and rarely found outside the office environment.

However, an ordinary cheap microcassette recorder can be used provided a couple of extra features are added. It should be prevented from stopping in the middle of a word so that everything played is intelligible, to remove the need for backspacing, and it should be possible to control it from a footswitch.

This is what the *Easy-Typist* does. The text is recorded in short "bursts" of as many words as the typist can reasonably remember, with brief silences of about a second between bursts.

This is much easier to do than it sounds and requires very little practice, certainly far less than the "training" required by most voice-recognition software products. It can then be played back with the recorder connected to this project which stops it automatically at each brief silence, allowing the pre-



Easy-Typist linked to a microcassette, earpiece, and the footswitch.

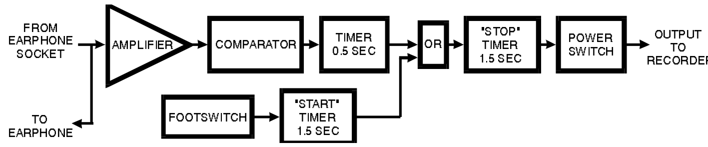


Fig.1. Simplified block diagram for the Easy-Typist.

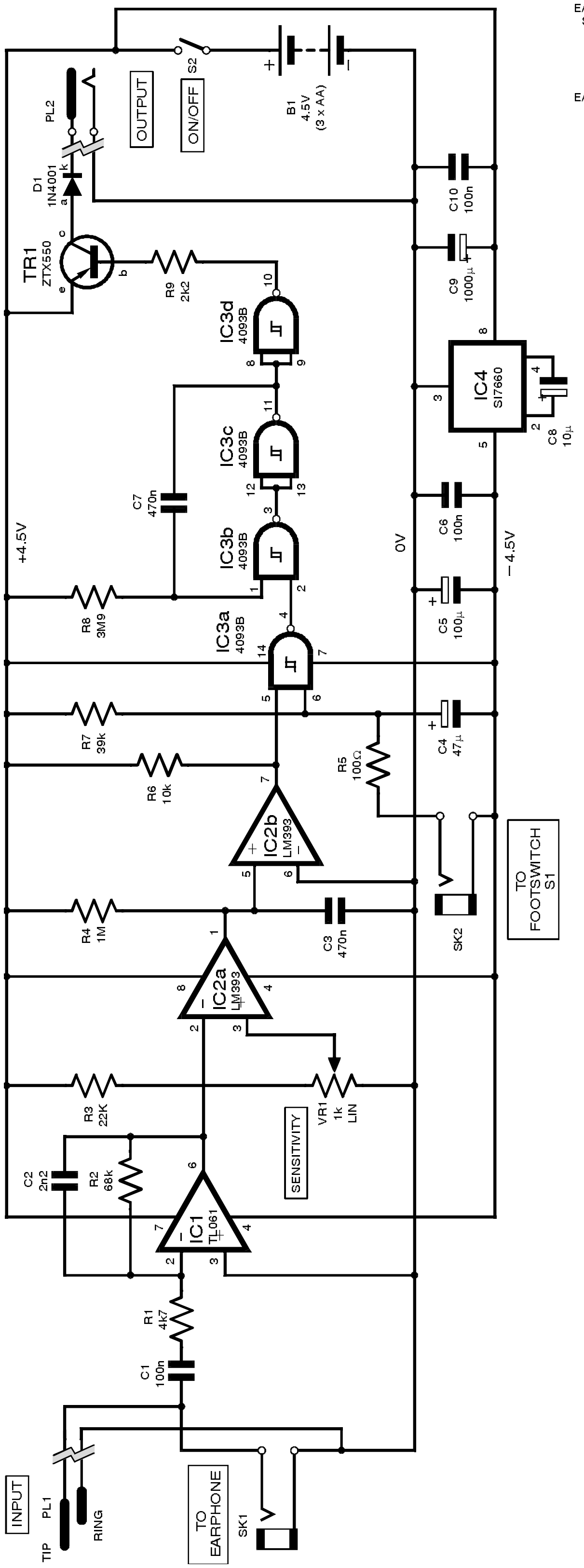


Fig.2. Complete circuit diagram for the Easy-Typist Tape Controller.

ceding phrase to be typed before playback is resumed by a press of the footswitch.

The whole process is simple, rapid and inexpensive to implement since it will work with the cheapest of microcassette recorders. It can also be used with any old computer that will run a wordprocessor, or even with a typewriter.

OTHER APPLICATIONS

Although the intended use is easier typing, other applications for this project will include anything where audio information has to be dished out in discrete chunks with the user operating a switch of some kind to continue to the next section. Audio presentations and displays, operating instructions and perhaps drivers' navigation information would all be practical uses.

The direction lists generated by programs such as "Autoroute" would be ideal for it. Items such as instrument readings or test notes could be made directly to a recorder and written up easily later. No doubt readers will be able to think of many more applications.

As mentioned, microcassette dEasy-Typist linked to a microcassette, earpiece, and the footswitch.

ictation recorders are now readily available and very cheap with some models costing under 20 UK Pounds. Provided the recorder has earphone and external power sockets and operates from a 3V supply (2 x AAA batteries is common) it can be used with this project. It is not necessary to modify it in any way, so any guarantee in force will not be affected.

HOW IT WORKS

A block diagram of the *Easy-Typist* is shown in Fig.1. The signal from the recorder's earphone socket passes straight through to the earphone, but is monitored by an amplifier with a voltage gain of about eleven.

The amplifier is used because at normal listening levels the voltage across an earphone is very small, typically only a few millivolts. It also allows some control of the frequency response, which improves circuit performance.

The amplifier drives a comparator. Each time the voltage of the amplifier's output waveform exceeds the reference set by the sensitivity control, the comparator

restarts a timer which runs for about half a second to deal with the natural gaps found even in continuous speech.

The output from this is combined with the input from the footswitch so that either will operate the output, again through a timer, which in this case operates only when the circuit switches off to ensure a positive turn-off action. The footswitch also has a timer, so that a quick press always operates the recorder for long enough to reach the next bit of speech.

Finally, there is an electronic switch to control power to the recorder itself. To avoid the need for modifications to the recorder it is started and stopped by using an external power supply and turning this on and off. Plugging an external supply into these recorders normally disconnects the internal batteries, so the *Easy-Typist* supplies power, in this case via a transistor.

CIRCUIT DESCRIPTION

The full circuit diagram for the *Easy-Typist* is shown in Fig.2. The input signal from plug PL1 is returned to the earphone socket SK1 but is also connected to the amplifier opamp, IC1 which has a voltage gain of eleven at 650Hz. An overall "speech" bandwidth of about 200Hz to 2kHz is set by capacitors C1 and C2.

Whenever the amplifier output exceeds the reference level set by Sensitivity control VR1, comparator IC2a discharges capacitor C3, causing the output of IC2b to go low. IC2a and IC2b have open collector outputs to which load resistors R4 and R6 are connected from the positive power supply. It takes C3 about half a second to recharge via R4 to the point where IC2b's output returns to the high state, giving the "timer" action needed to keep running with normal speech.

Combination with the signal from the footswitch is performed by the Schmitt NAND gate IC3a. Taking either of the inputs of this gate low causes its output to go high.

When footswitch S1 is operated it discharges capacitor C4. The time taken for resistor R7 to recharge this capacitor guarantees around 1·5 seconds running time following switch operation.

The next two gates, IC3b and IC3c, ensure a positive switch-off action. When the input from IC3a goes low, the output of IC3b goes high and the output of IC3c goes low. This is fed back to the other input of IC3b through capacitor C7, ensuring that the "off" state is maintained for at least the 1·5 seconds it takes for this capacitor to charge through resistor R8.

POWER PLAY

Finally, IC3d inverts the signal to give the correct polarity of base drive to transistor TR1, which controls the power to the microcassette recorder. Diode D1 reduces the voltage slightly as a 4·5V supply with only the drop introduced by TR1 might damage a recorder intended to operate from 3V. In practice a single diode here gives about the right output voltage.

The supply for this circuit is taken from three "AA" cells giving 4·5V. The SI7660 "voltage converter" IC4 generates a *negative* supply for the opamp and the comparators, which gives them a more suitable working voltage and also allows the battery negative to be used as the circuit "ground" (0V) to simplify the design.

Supply decoupling capacitors are provided, these are C5, C6, C9, and C10 . The unusually large value of C9 is intended to absorb the start-up surges of the recorder's motor. Output to the recorder is from plug PL2, whilst switch S2 is provided to switch off the power when the unit is not in use.

CONSTRUCTION

Construction of this project is straightforward although it does call for a fine-tipped soldering iron. All the components are assembled on a piece of 0·1in. matrix stripboard, 14 strips by 33 holes. The topside component layout and details of breaks required in the underside copper tracks are shown in Fig.3.

The thirty-eight breaks should be made first. It's worth checking these carefully with a strong magnifying glass before continuing as an almost invisible strip of copper sometimes remains around the edge of a break and can be very difficult to find later.

Following this the 21 links should be fitted. These should be followed by the resistors, diode D1, the small capacitors, and transistor TR1. Finally, the sockets for the four ICs should be fitted, followed by the electrolytic capacitors.

It will be seen that some of the small ceramic capacitors have their leads bent outwards to accommodate a wider hole pitch; where this is necessary care is needed to avoid breaking them. There are seven external connection points on the board. The use of solder pins for these is highly recommended as they provide more

robust connections, which can be made from the component side.

COMPONENTS

Resistors
R1 4k7
R2 68k
R3 22k
R4 1M
R5 100 ohms
R6 10k
R7 39k
R8 3M9
R9 2k2
All 0.6W 1% metal film

Potentiometer
VR1 1k rotary carbon, linear

Capacitors
C1, C6, C10 100n resin-dipped ceramic (3 off)
C2 2n2 resin-dipped ceramic
C3, C7 470n resin-dipped ceramic (2 off)
C4 47u radial electrolytic, 10V
C5 100u radial electrolytic, 10V
C8 10u radial electrolytic, 63V
C9 1000u radial electrolytic, 10V

Semiconductors
D1 1N4001 1A 50V rectifier diode
TR1 ZTX550 *pnp* silicon transistor
IC1 TL061 opamp
IC2 LM393 dual comparator
IC3 4093B CMOS quad 2-input NAND Schmitt trigger
IC4 SI7660 voltage converter

Miscellaneous
PL1 3.5mm mono jack plug
PL2 DC power plug (see text)
SK1 3.5mm mono chassis socket
SK2 6.35mm mono chassis socket
S1 footswitch, momentary press-to-make type
B1 4.5V battery pack (3 x AA cells in holder).

Stripboard 0.1in matrix, size 14 strips x 33 holes; plastic case, size 118mm x 98mm x 45mm approx; 8-pin DIL socket (3 off); 14-pin DIL socket; control knob; connecting wire, solder pins, solder, etc.

See also the SHOP TALK Page!

Approx. Cost Guidance Only (Excl. footswitch & batts) $24

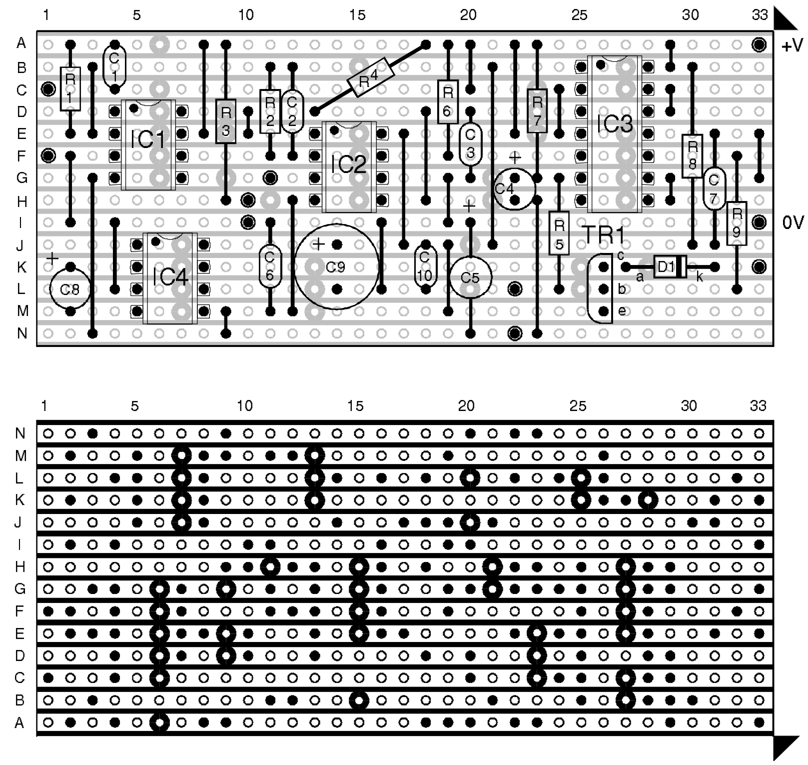
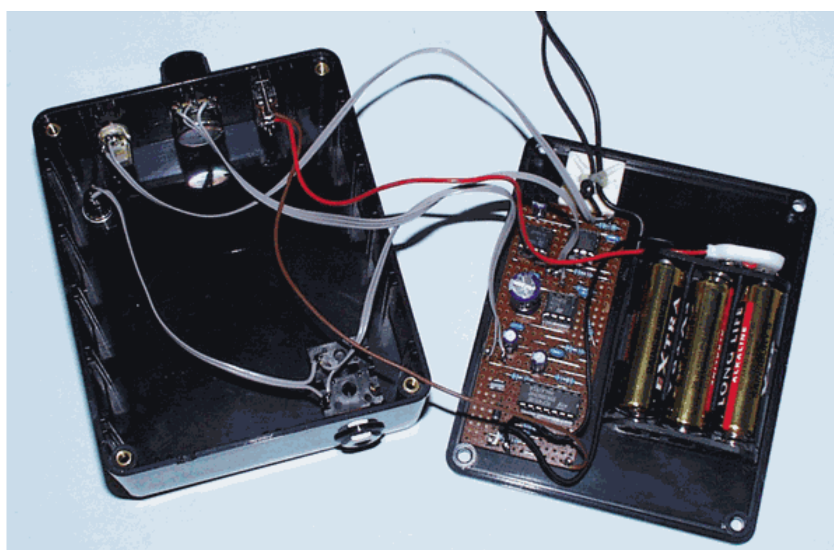


Fig.3. Easy-Typist stripboard component layout and details of breaks (38) required in the underside copper tracks.



Completed unit showing the circuit board and battery holder mounted on the lid.

FIRST TESTS

A useful initial test is to power the board without any of the ICs inserted, preferably from a current-limited bench supply.

Apart from a brief surge as the decoupling capacitors charge, there should be virtually no current drain. The reason for this test is to check there are no major short-circuits present without

risk to the ICs.

If all seems well IC4 can be inserted. When powered again with 4·5V, a 9V supply should appear across pin 4 and pin 7 of IC1's socket, pins 4 and 8 of IC2's socket and pins 7 and 14 of IC3's socket.

If this checks out, IC1 can be plugged in. With no input, output pin 6 should settle to around 0V (using the battery negative as the reference point). Next, IC3 can be inserted. Once capacitor C4 has had time to charge, both inputs (pins 5 and 6) to IC3a will be high, so IC3 pin 4 should be low, pin 3 should be high, pin 11 low and pin 10 high so transistor TR1 should be off. Shorting the connections for footswitch S1 should reverse all these polarities and cause the output to appear from TR1 collector (c) and diode D1.

SPEECH TEST

It should now be possible to test the stage around IC2 using a recorder with an earphone and some recorded speech. At this stage the recorder can operate from its internal batteries, there is no need to connect it to the supply from this project. The earphone must be connected though, since most recorders of this type use a series resistor to reduce power to the earphone

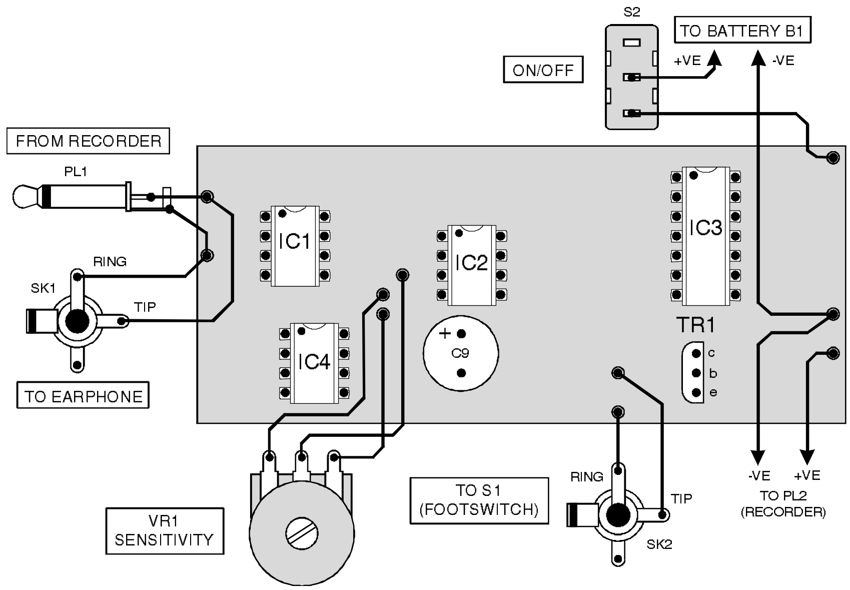


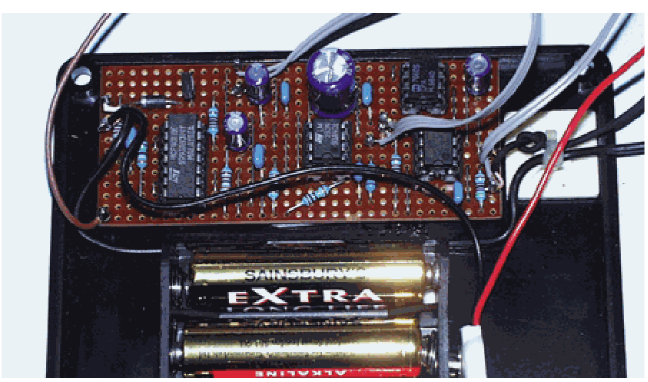
Fig.4. Interwiring from the circuit board to off-board components. The two plugs, PL1 and PL2, are wired on extended leads.

and if it is not present the output voltage will rise considerably.

The output of IC2b should be monitored with a meter and the recorder should be played at normal volume through the earphone. The output of IC2b, at pin 7, should be low whilst the speech is playing and go high when it stops. Some adjustment to Sensitivity control VR1 will probably be necessary to achieve this, although the setting of this control has not proved to be at all critical.

A recording of some speech with appropriate one-second silences will be found useful for this test. Remember that, when the speech stops, it will take around half a second for the output of IC2b to go high. Checking the output of IC2a is not recommended unless an instrument with a very high input impedance is available.

A signal generator could be used in place of the recorder, of course. If this is available, it should be set to inject a level of 5mV RMS. (15mV peak-to-peak) at about 600Hz to 700Hz. If this works, the output from



Circuit board component layout and wiring.

Completed Easy-Typist showing the additional pause-switch button on top of the case.

transistor TR1 and diode D1 can be checked as operating correctly with the sound input present and absent.

BOXING-UP

With all tests completed and correct, the board can be fitted into a case of the user's own choice and connected as shown in Fig.4. In the prototype, the Input plug PL1 is a 3·5mm mono jack plug dangling on a short lead, whilst the Earphone socket SK1 is a 3·5mm mono chassis socket attached to the case. The power plug PL2 for the microcassette recorder is one of the miniature DC power plugs used with many items these days, the exact type and connection polarity will depend on the recorder it is to be used with.

The footswitch was purchased as an inexpensive ready-to-use item. It came with a standard 6·35mm mono jack plug so a socket for this was fitted to the case. Although not shown, a small pushbutton switch is fitted to the case and connected in parallel with the footswitch socket for applications where operation with this is more convenient.

MISSING LINK

A comment regarding the pitfalls of working with stripboard can be made here. Sharp-eyed readers may spot a link to the right of R6 at the top of the board which connects positive supply to a section of track with a break at either end, but going to nothing else.

Originally this link was not present. Neither was the right-hand track break so this section of track was connected to IC3 pin 2 and, more importantly, IC3 pin 4. This wouldn't be a problem since it didn't connect with anything else, right?

Wrong! The next track down connects to pin 1 and pin 5 of IC2, and capacitance between stripboard tracks can be astonishingly high. When IC2 pin 1 turns off, the connection to it becomes high-impedance, even though it is connected to ground by the 470n capacitor C3.

The scenario, then, went as follows. IC2 output turned off and the voltage across C3 rose slowly as it charged from resistor R4. When it reached ground potential, IC2b changed state, causing IC3a output to go low. A bit of this transition to the low state was fed back into C3 through the inter-track capacitance, pulling it down enough to cause IC2b to switch on again and the final result was a slow oscillation.

So, the circuit which had functioned perfectly as a breadboard "rats-nest" refused to behave as a neatly constructed stripboard unit! Worse, it worked fine without either IC2 or IC3, but not when both were present, so the immediate assumption was that there must be a short-circuit or a missed break between these two.

It took around three hours to figure out the true cause of the malfunction. The cure, of course, was to remove the feedback path by disconnecting the unused track section with an extra break, and to improve on this by tying it to the nearest supply rail. This is a good example of the type of problem that can befall the unwary stripboard user which may be helpful to others encountering similar troubles.

THE LAST WORD

To finish, here are a few more possible uses for this little gadget. It would make an ideal prompter for use when giving talks or speeches. It could be used for audio-visual training, or by actors learning their lines.

Finally, it might render its original purpose obsolete by helping to train the user in touch-typing!

Go to next section

A selection of ELECTRONIC CD-ROMS for Hobbyist and Students

Computer Desktop Encyclopedia

The award-winning source of computer terms, concepts, important products and interesting stuff!! An invaluable reference and an unmatched resource for anyone interested in computers. **($14.99 Special Offer! -- While Stocks Last!)**

The PhizzyB Computer Simulator

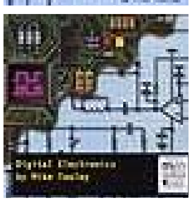
The *PhizzyB Simulator* provides an accurate representation of the real *PhizzyB*, including the ability to step and run through programs. Comes equipped with an assembler and other tools, plus user manuals (as PDF files on the CD ROM).

PICtutor by John Becker

This CD-ROM, together with the PICtutor development board (as described when you click on "more info"), will teach you how to use PIC microcontrollers. The board also acts as a development test bed and programmer for future projects.

Electronic Circuits & Components

This CD provides an introduction to the principles and application of the most common types of electronic components, and shows how they are used to form circuits. The CD also includes the "Parts Gallery".



Digital Electronics (Mike Tooley)

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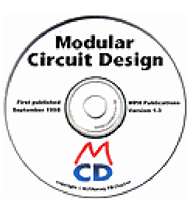

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VOLTAGE MONITOR by ROBERT PENFOLD

Keep an eye on your battery's condition with this low-cost starter project.

This simple *Voltage Monitor* device has two light-emitting diode (LED) indicators that switch on if the monitored supply voltage falls below separate threshold levels. The obvious application is in battery operated equipment where erroneous results could be obtained if the battery potential falls below a critical level.

Having twin threshold levels is very useful, as one can be set slightly above the critical voltage, and it will then give a warning if the battery will soon need replacement. The circuit can also be used with mains powered equipment to monitor the DC supply voltage, and it will then give a warning if the supply voltage drops to an inadequate level due to a malfunction.

ON THE THRESHOLD

With the specified resistor values the circuit provides threshold potentials of 10V and 12V, but by altering the values of four resistors these voltages are easily changed. They can be set at any potentials from about 3·5V to 30V, but note that the supply voltage to the monitor circuit must never exceed 36 volts. The mathematics required to work out the modified circuit values is extremely simple – more later.

For battery monitoring applications the current consumption of the monitor is a critical factor. There is no point in having a monitor that draws such a high supply current that battery life is greatly reduced.

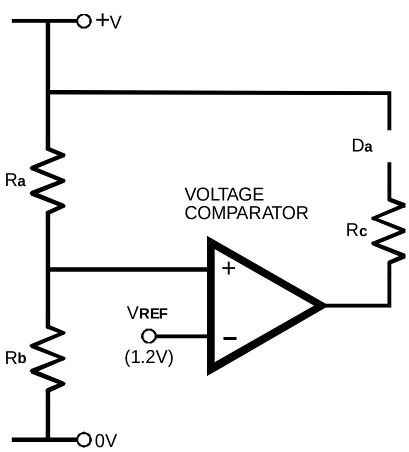

Fig.1. The basic arrangement for each voltage

This circuit has a typical current consumption of around 0·6mA under standby conditions. This should not greatly reduce the operating life of even a low capacity battery such as a PP3 type. The current consumption increases by about 4mA per LED when the circuit is activated.

COMPARATOR

The *Voltage Monitor* circuit is based on the two voltage comparators in an LM393N IC. A voltage comparator is very

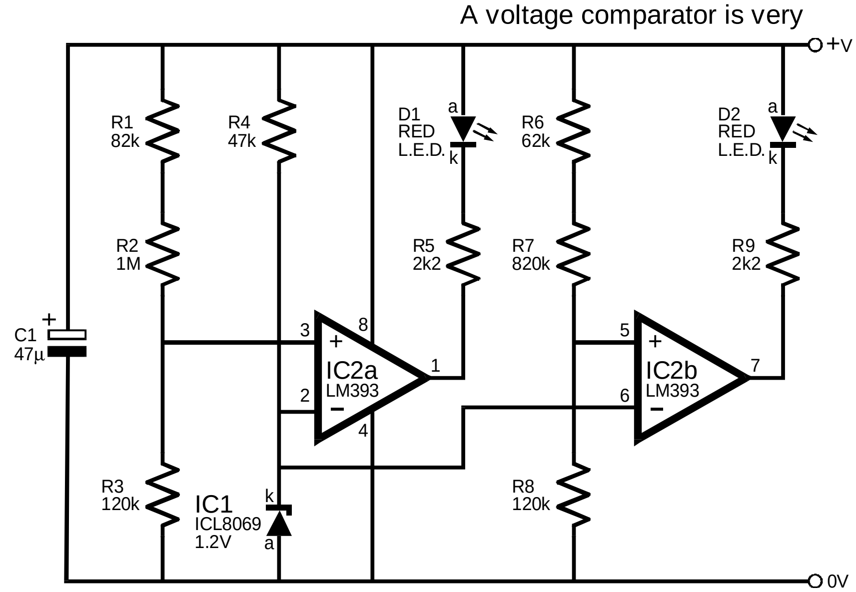

Fig.2. Full circuit diagram for the Voltage Monitor. It is essential that an in-line fuseholder, with a 100mA fuse, is included in the positive supply input lead if the monitor is to be installed in a car, boat, caravan etc.

similar to an operational amplifier (opamp). Like an operational amplifier, each comparator has inverting (–) and non-inverting (+) inputs. If the non-inverting input is at a higher voltage than the inverting input the output goes high, and if the inverting input is at the greater voltage the output goes low.

This is again the same as for an opamp, but there is a subtle difference in that the output stage of a comparator is an open collector type. In other words, there is a switching transistor at the output that is used to control a load of some kind. The load in this case is a LED indicator.

The basic scheme of things used in each of the voltage detector circuits is shown in Fig.1. The inverting input (–) of the comparator is fed with a highly stable reference potential of 1·2V, and the non-inverting input (+) is fed from the supply lines via a potential divider (Ra/Rb). A certain fraction of the supply voltage is therefore fed to the non-inverting input, and this fraction is controlled by the values of resistors Ra and Rb.

Suppose that the potential divider provides one tenth of the supply voltage to the non-inverting input. With a supply potential of 12V or more there will be 1·2 volts or more at the non-inverting input, and the output transistor of the comparator will be switched off.

If the supply voltage falls below 12V, the potential fed to the non-inverting input goes below 1·2V, and the inverting input is then at the higher voltage. The output transistor of the comparator then switches on and activates LED Da. Resistor Rc limits the output current to the required level.

COMPONENTS

Resistors
R1 82k
R2 1M
R3, R8 120k (2 off)
R4 47k 5% carbon film
R5, R9 2k2 5% carbon film (2 off)
R6 62k
R7 820k
All 0.6W 1% carbon film unless noted

Capacitor
C1 47u radial electrolytic, 40V

Semiconductors
D1, D2 5mm red LED (2 off)
IC1 ICL8069 voltage reference
IC2 LM393N dual comparator

Miscellaneous
Stripboard, size 0.1 inch pitch, having 20 holes by 17 strips; 8-pin DIL socket; multistrand connecting wire, solder pins, solder, etc.

See also the SHOP TALK Page!

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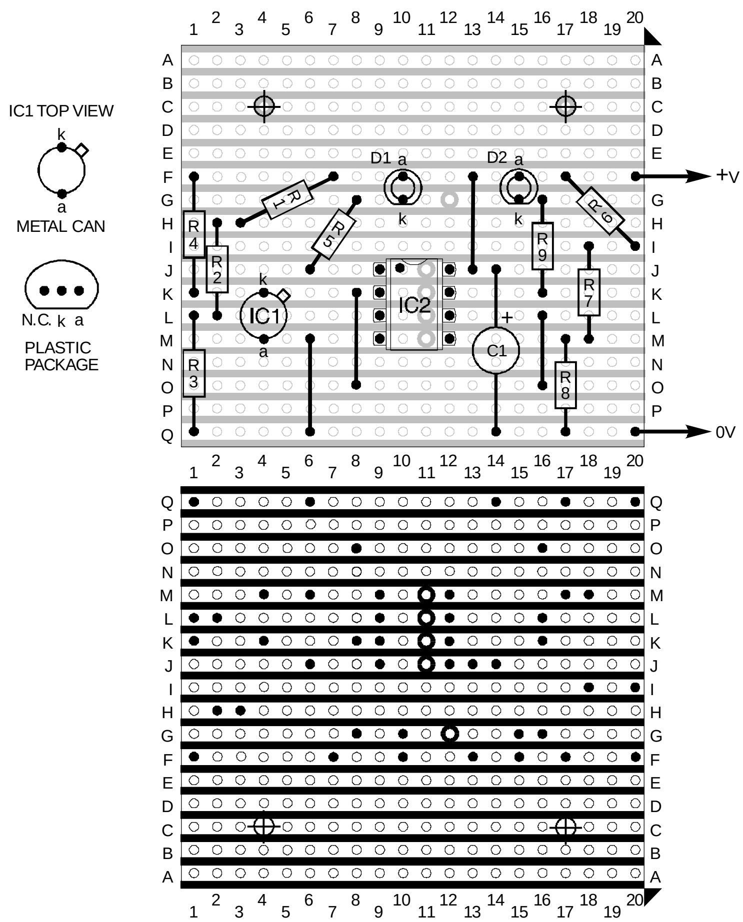


Fig.3. Stripboard topside component layout and details of breaks required in the copper tracks.

CIRCUIT DETAILS

The full circuit diagram for the *Voltage Monitor* appears in Fig.2. The two comparators, within IC2, share a common voltage reference, and this is a simple shunt regulator that has resistor R4 as the load resistor and IC1 as the voltage stabilizer.

The ICL8069 used in the IC1 position is a highly accurate and stable voltage reference chip, and not a simple Zener diode. It will operate efficiently at currents as low as 50uA, which is important in this application where low current

consumption is a definite asset. It operates at a current in the region of 200uA in this circuit.

THRESHOLD VOLTAGES

The threshold voltage of the detector based on IC2a is determined by the values of resistors R1, R2, and R3. Two resistors in series are used in the upper arm of the potential divider because this enables the threshold value to be set accurately using ordinary preferred values.

With resistor R3 at 120 kilohms (120k), the threshold voltage is equal to one volt per 100 kilohms of resistance through the potential divider. This resistance is fractionally more than 1200k (1·2 megohms), giving a threshold voltage of 12V.

The switching voltage of the other comparator is controlled by the values of resistors R6, R7, and R8. With fractionally more than 1000k (1M) of resistance through the potential divider this gives a threshold potential of 10V.

It is easy to work out the resistance values for other threshold voltages provided resistors R3 and R8 are left at a value of 120k. Multiplying the required voltage by one hundred gives the total resistance through the potential divider in kilohms. Deducting 120 from this then gives the total resistance through the upper section of the divider. In other words, this gives the required series resistance through R1 and R2, or R6 and R7 in the second voltage detector.

As an example, suppose that a threshold potential of 7·5V is required. Multiplying 7·5 by 100 gives a total resistance for the potential divider of 750k. Deducting 120k from this gives an answer of 630k through the upper arm of the divider.

The required value is unlikely to conveniently match up with a preferred value, and this is certainly the case here. The nearest preferred value to 630k is 620k, which is actually an error of under two-percent. In some applications this margin of error is acceptable, and it would then be in order to use a value of 620k for resistors R1 or R6, and a link wire for R2 or R7. If an error of two percent is not acceptable, a 10k resistor and a 620k component in series give exactly the required resistance of 630k.

Things will not always work out quite this well, and in some cases it might be necessary to accept a small error even if two resistors are used. However, the error should only be a fraction of one percent, which is insignificant.

CURRENT AFFAIRS

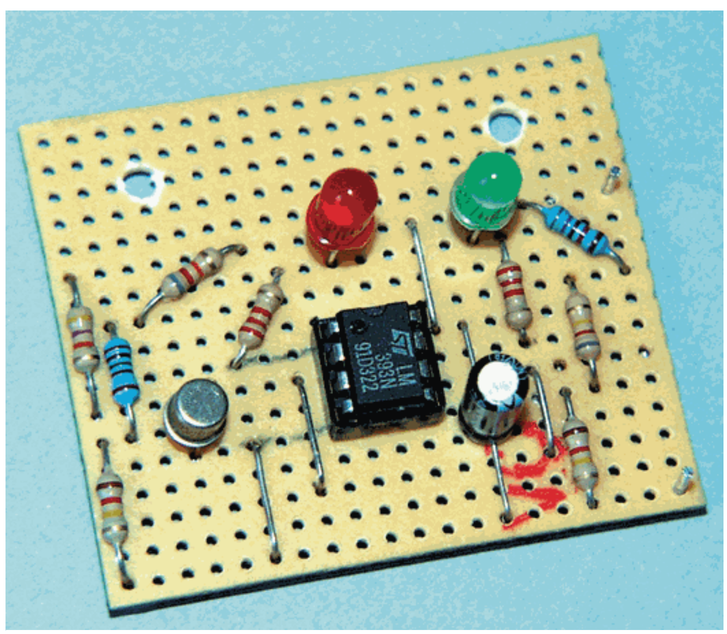
The LED current and brightness will be quite low if the unit is used to detect low threshold voltages of around five volts. To compensate for this, resistors R5 and R9 should be reduced from 2k2 to 1k.

Similarly, at high threshold potentials of around 20V to 30V, the LED current will become relatively high, although it should still be no more than about 13mA per LED. Increasing the value of R5 and R9 to 3k9 will keep the LED current at about 5mA.

The operating current of IC1 varies enormously over the operating voltage range of the circuit, but with the specified value of 47k for resistor R4 the operating current remains within the acceptable range for the ICL8069.

CONSTRUCTION

Construction of the *Voltage Monitor* project is extremely simple indeed, and it should be within the capabilities of complete beginners. The circuit is



Layout of components on the completed Voltage Monitor circuit board.

built on a piece of stripboard and the component layout, together with details of the breaks required in the underside copper tracks, are shown in Fig.3.

The stripboard measures 20 holes by 17 copper strips, and a board of this size is trimmed from one of the standard size pieces using a hacksaw. Stripboard is quite brittle, so cut carefully along rows of holes using a minimum of force. File any rough edges to a neat finish and then drill the two 3mm diameter mounting holes and make the five breaks in the copper strips.

The board is now ready for the components and link-wires to be fitted. With a small board such as this it is not necessary to worry too much about the exact order in which the components are fitted, but it is probably best to fit the resistors and link-wires first, followed by the single capacitor and the semiconductors.

The four link-wires are quite short and they can be made using some of the wire trimmed from the resistor leadouts. Be careful to fit capacitor C1 with the correct polarity. Use single-sided solder pins at the two points where the supply will be connected to the board.

Although it is not a static-sensitive component, it is still a good idea to mount the LM393N comparator, IC2, on the circuit board via a holder. There is a slight complication with IC1, which is produced in both metal cased and plastic encapsulated versions. The metal cased version (two pins), as used on the prototype, is shown in Fig.3.

However, it is actually the plastic cased version (three pins) that is available from most suppliers these days. With the plastic version the flat side of the case should be on the left as viewed in Fig.3 (i.e. facing towards resistors R2 and R3). Ignore the pin marked NC (which stands for “no connection”).

ASSEMBLY

To some extent the way in which the unit is constructed and used will depend on the precise application. It can be built into a small plastic or metal box and connected to the main equipment via a twin lead. In most cases, however, it is more likely to be incorporated into another project.

Either way, the circuit board and LEDs can be dealt with in two ways. Either the board can be mounted on the case and hard wired to the LEDs on the front panel, or the LEDs can be mounted on the circuit board and then fitted into holders on the front panel of the case.

Due to the small size and weight of the circuit board this second method works well with any LED holders of reasonable quality. If the LEDs are not mounted on the circuit board, fit single-sided solder pins on the board in place of the LEDs. The pins provide an easy means of making reliable connections to the board.

Make sure the LEDs are connected with the correct polarity. The cathode (k) leadout of an LED is normally indicated by a shorter leadout wire and that side of the case being flat.

TESTING

If a suitable variable voltage supply is available, connect the output of the supply to the input of the monitor circuit and vary the voltage around the threshold levels. With the supply potential above the threshold levels both LEDs should remain off, but reducing the supply should result in the LEDs switching on at the appropriate threshold voltages.

For highly critical applications the threshold levels can be “fine tuned” by tweaking the values of resistors R1 and R6. An increase in value raises the threshold voltage, and a reduction in value decreases the threshold level. Provided one percent tolerant resistors are used in the potential dividers the accuracy of the circuit should be very good though, and for most applications no adjustment to the values should be needed.

In the absence of a suitable power supply the unit can be given a rough check using some batteries. Use a battery or batteries in series to provide a supply potential that is somewhat higher than the higher threshold level. With 10V and 12V threshold voltages for instance, a 15V or 18V battery supply could be used. Both LEDs should be switched off when using this supply potential.

Now try a lower battery voltage that is slightly less than the lower threshold level. For example, a 9V battery could be used with 10V and 12V threshold levels. Both LEDs should then switch on.

If there is any sign of a malfunction, disconnect the supply immediately and recheck the circuit board for errors.

IN USE

Note that it is essential to wire an in-line fuseholder fitted

with a low current fuse (about 100mA) in the positive supply lead if the unit is used to monitor the supply of a car, boat, caravan, etc. Otherwise there is a risk of a fault causing a very large current to flow, which could result in a fire.

Experienced constructors should have no difficulty in using the unit to monitor the DC supply voltage of a mains powered project, but this is something that should not be attempted by those of limited experience.

Make sure the monitor is connected to the supply with the right polarity. The semiconductors and C1 could be damaged if the supply connections are reversed.

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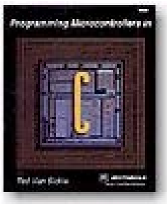

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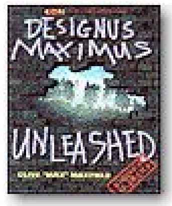

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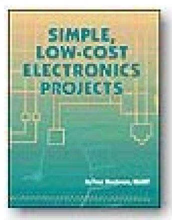

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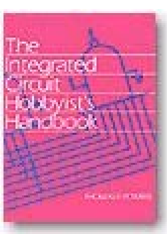

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Constructional Project

PIC VIDEO CLEANER by MIKE DELANEY

Improve your PICture quality.

This project is the result of a visit by the author to a friend's home to see a video recorder and portable TV the friend had installed in his son's bedroom that was giving trouble. He was complaining that the picture was "flickering" and the brightness varying.

The brightness variation was particularly noticeable when watching at night with the light turned down low. Both of the units had been obtained from second-hand shop, and they did not want to know about any problems.

Using a known good tape and head cleaner etc., the system was duly checked out. After much experimentation it was discovered that the problem lay with the tape – a recently-purchased "Block Buster'' – because the good tape, along with his home-recorded tapes, all worked fine. You could see that the picture flickered and the brightness was indeed wavering, but this did not happen with the same movie on the main TV in the lounge.

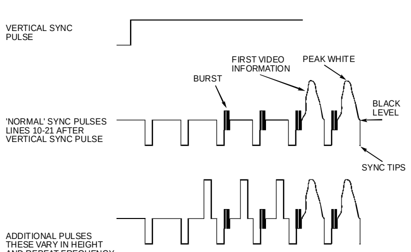


Fig.1. Sync pulse showing interference details.

Making further inquiries, from another friend who is in the TV trade, it transpired that the problem was caused by something called "Macrovision*", which is a VCR-to-VCR copy-prevention system. This purposely introduces interference pulses on the video tape. Not all sets are disturbed in this way, and it was suspected that the portable was simply over-sensitive. Searching on the Net, an article was discovered which described these pulses in detail.

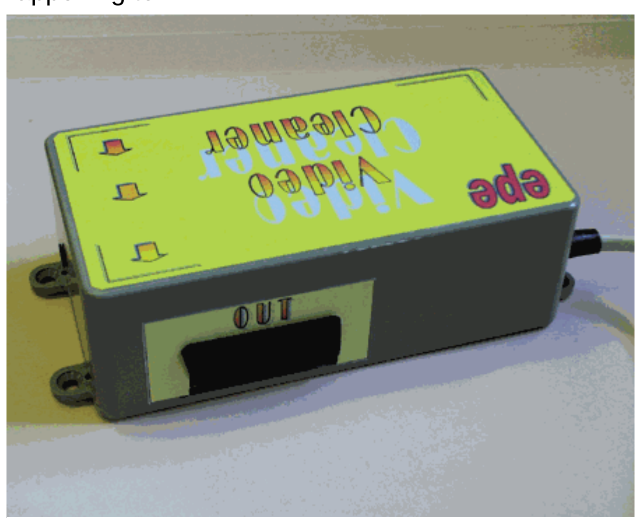
MAKING A START

"First identify the cause" seemed a good approach. This entailed using a video sync-separator IC, type LM1881 from National Semiconductor, to see exactly what was happening to the signal on an oscilloscope. The LM1881 has been around for a long time and all the application data that was needed came from National's web site.

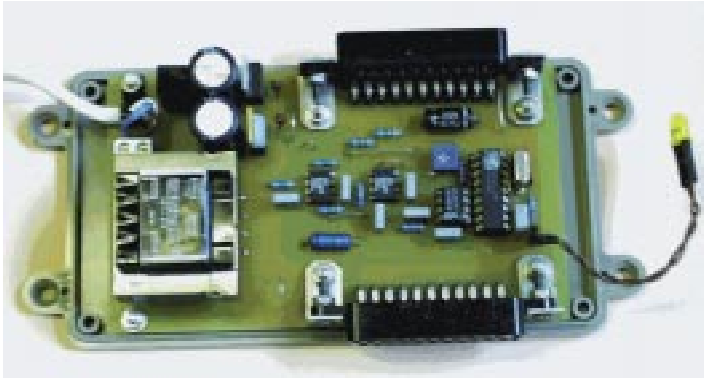
Breadboarding revealed some strange goings-on indeed! It was not surprising that the portable TV was having a struggle. The resulting sync pulse waveform, showing details of the introduced "interference", can be seen in Fig.1.

This simplified diagram shows the difference between a "clean" signal and the interference pulses added to prevent tape-to-tape copying. VCRs use the amplitude of the black level voltage immediately following the Line Sync pulse to set their AGC level. They also rely on incoming sync pulses on the video information, unlike TVs which have their own sync circuits built in. Because the added pulses are variable both in amplitude and repeat timing the brightness of the picture can vary and the line and frame stability can be affected to a point where it is almost unrecognizable.

These interference pulses



PIC Video Cleaner showing input SCART



are added between the end of the frame-sync pulse and the first video information. They repeat at intervals of about two seconds and are themselves in sync with the line-sync pulses. In this way they do not stop the average TV from working satisfactorily, but prevent copying (despite the fact that Copyright laws allow you to make a back-up copy of any legally purchased tape for your own use), and in my friend's case sometimes interfere with a sensitive TV.

ON THE LINE

Clearly it would be necessary to remove the interference pulses and replace them with an appropriate DC level, since the TV or VCR requires a reference voltage to set its brightness. The first twenty or so lines following the vertical sync pulse are not seen on a correctly set up TV, so it does not matter if they are lost.

However, it is necessary to allow the color burst and correct horizontal sync pulses through during this time, otherwise it would upset the operation of the TV. Therefore, it is not just a case of erasing all information up to the start of the video information.

There is occasionally more interference added for a period of about a dozen lines before the vertical sync pulse, and this

DETAIL OF SYNC PULSE AND BURST

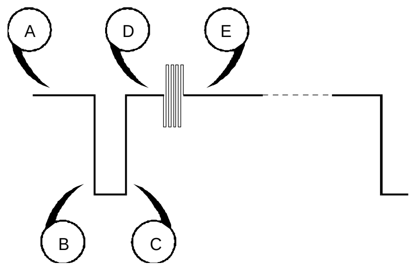


Fig.3. Sync timing of the PIC used to clean up the output from the video recorder. (A) Enable gating to check for falling edge of line (horizontal) sync pulse. (B) Line Sync detected. Turn on IC3 to allow video sync through. (C) Turn off IC3, turn on IC4 and allow black level through. (D) Turn off IC4, turn on IC3 to allow burst through from video. (E) Turn off IC3, turn on IC4 to allow black level voltage through. Wait for approximately 60us before looping back to (A).

must also be taken into account when designing any circuit.

BLOCK DIAGRAM

A simplified block schematic for the *PIC Video Cleaner* is shown in Fig.2.

The Sync Separator LM1881 splits the video sync signal into its constituent parts, two of which, Composite Sync and Frame Sync, are used by

COMPONENTS

Resistors
R1 680k
R2, R7, R8 75 ohms (3 off)
R3, R4 750 ohms (2 off)
R5, R6, R9 1k (3 off)
All 0.6W 1% metal film

Potentiometer
VR1 2k cermet preset

Capacitors
C1, C2, C3, C7 to C10 100n polyester (7 off)
C4, C5 22p ceramic disk (2 off)
C6 6u8 axial electrolytic, 16V
C11 22u axial electrolytic, 16V
C12, C13 1000u radial electrolytic, 16V (2 off)
C14, C15 1u tantalum bead (2 off)

Semiconductors
D1 5mm red LED
REC1 1A 25V bridge rectifier
IC1 LM1881N video sync separator
IC2 PIC16F83-10P microcontroller preprogrammed (10MHz version)
IC3, IC4 AD810 low-power current-feedback video amp with disable (2 off)
IC5 7805 +5V 1A voltage regulator
IC6 7905 -5V 1A voltage regulator

Miscellaneous
X1 10MHz crystal
T1 3VA mains transformer with 0V-6V,0V-6V@0.25A secondary
SK1, SK2 21-pin right-angle SCART socket (2 off)
SK3 2-way PCB-mounting mains connecting block (10A 230V AC)

Printed circuit board available from the *EPE Online Store*, code 7000251 (**www.epemag.com**); plastic case, size 44mm x 146mm x 75mm internal; 8-pin DIL socket; 18-pin DIL socket; L-shaped support metal bracket (4 off); multistrand connecting wire; mains cable; 3mm nuts, bolts, and washers (6 off each); PCB spacer (6 off); rubber grommet; P-clip for mains lead; LED clip; sleeving, solder, etc.

See also the SHOP TALK Page!

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(Excl. SCART skts & mains cable)

the PIC micrcontroller. The PIC synchronizes with these two inputs, and turns on either the

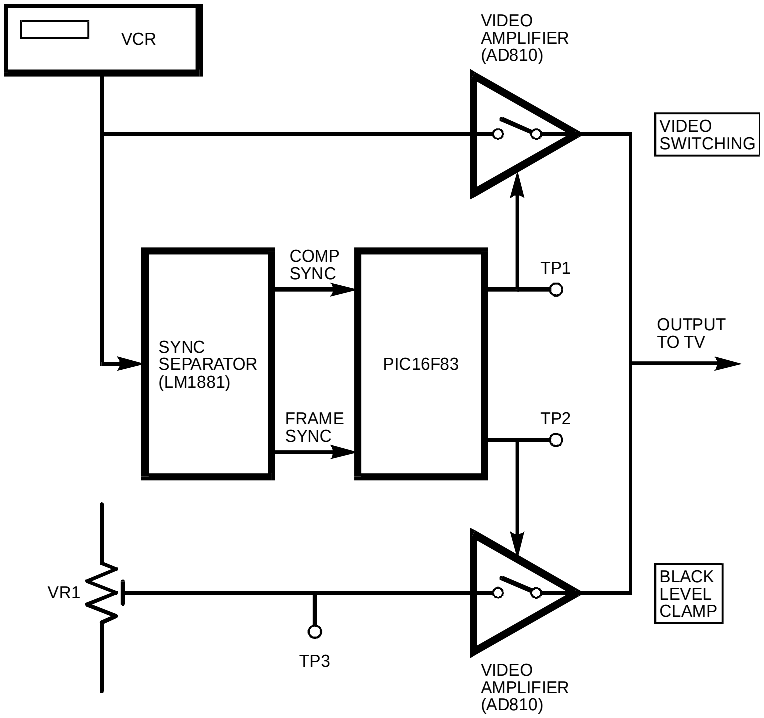


Fig.2. Video Cleaner block diagram showing video signal and control signal paths.

video switching IC (IC3) or the black level clamp IC (IC4).

FIRMWARE

Most of the work is done by the PIC microcontroller, and the sync timing waveform is shown in Fig.3. The cycle begins with the rising edge of the Frame Sync Pulse, following this the PIC waits for the next falling edge of the Line Sync Pulse (A). It is this which is used to start the cycle and subsequently determine which of the two AD810 multiplexers to turn on and which to turn off.

Each Line Sync pulse is detected and counted as it arrives. In this way the PIC remains in sync with the incoming video signal line-by-line.

After the first 25 or so lines following Frame Sync, all of the video information is allowed through. So for about the next 290 lines, C4 is turned off and IC3 is turned on and the PIC, IC2, simply counts in the Line Sync pulses.

After this period, more multiplexer switching is needed to eliminate the interference added just before Frame Sync goes low. The PIC then checks for Frame Sync and when this is detected the whole cycle repeats for the even field, and so on, *ad infinitum!*

CHOICE OF COMPONENTS

Initial tests using a 4MHz PIC microcontroller proved that it was too slow; the delay between detecting a sync pulse and responding to it was too great. Changing to a 10MHz device solved this problem. There is still some jitter, but this has no adverse effect on the observed image.

Video switching in the *Video Cleaner* is carried out by a pair of Analog Devices AD810 video amplifiers (Fig.4), which have a disable mode built in, thereby simplifying multiplexing. One is used for the video signal, while the other is merely for switching the black level voltage.

It was found in tests that the AD810s were very stable, not prone to bursting into oscillation, provided the PCB was carefully laid out.

The power supply is straightforward. The PIC requires +5V, which will suit the LM1881, and the AD810s need a split plus and minus 5V. Both of these are produced in the circuit by a split secondary transformer and two voltage regulators.

Note that the supplies to each IC are individually decoupled with 100nF capacitors. The regulators *MUST* be decoupled with *solid tantalum* capacitors placed very close to their pins. They have a far superior (less) leakage factor than electrolytic capacitors.

Standard right-angled PCB-mounting SCART connectors are used for signal input and output. If your VCR does not have SCART connectors, simply connect the video output to pin 20 of the SCART socket SK1, and take the output from pin 19 of SK2. It is not necessary to connect the sound through the circuit in this case.

CIRCUIT DETAILS

The sync separator, PIC microcontroller, and amplifier stages for the *PIC Video Cleaner* are shown in Fig.4. The regulated power supply circuit diagram is shown in Fig.5. ***(Note that this circuit is based on a UK 240V 50Hz mains power supply, and will have to be modified for other countries' power supplies. In***

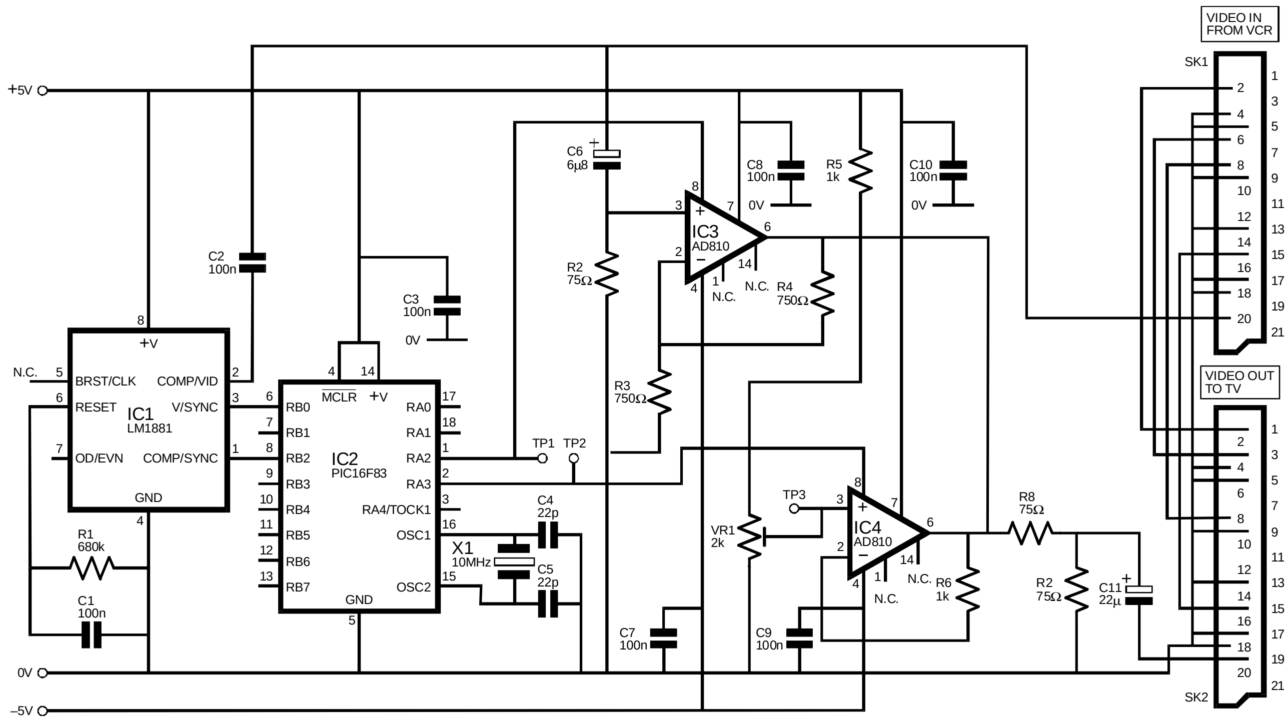


Fig.4. Main circuit diagram of the PIC Video Cleaner showing the sync separator, PIC microcontroller and input/output stages.

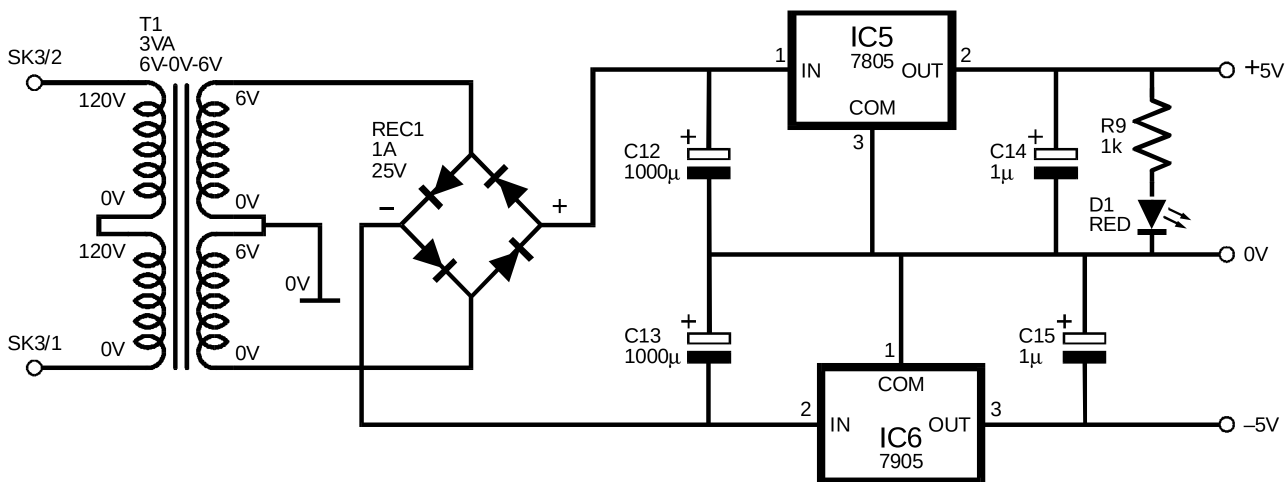


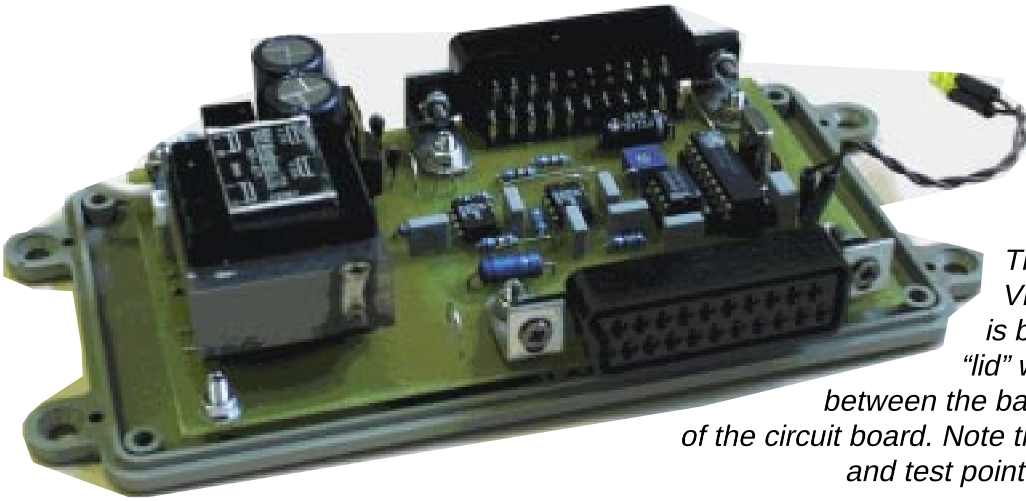
Fig.5. PIC Video Cleaner regulated power supply circuit diagram.

this case you should consult with a qualified electrician if you are in any way unsure as to what you are doing.)

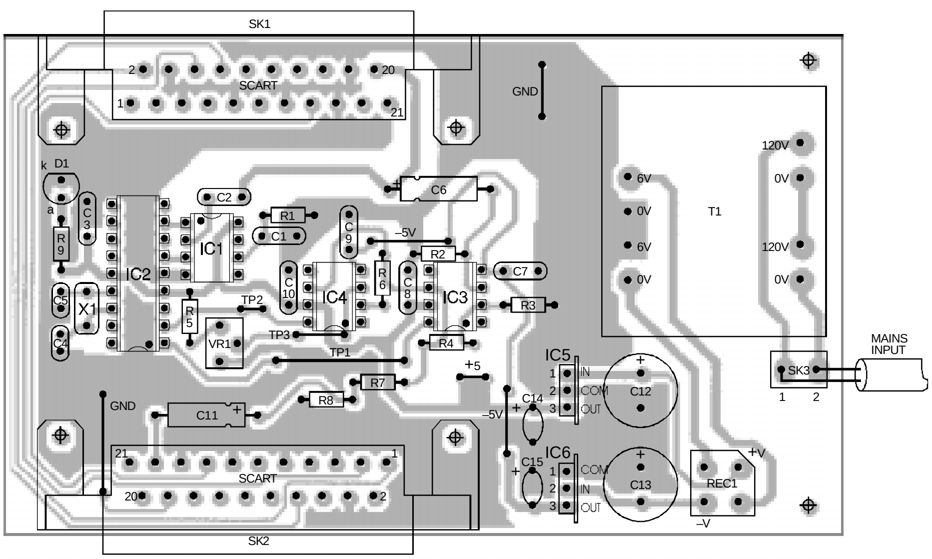
The incoming video signal, from pin 20 of input socket SK1, is AC coupled into IC3, the video switching AD810, by capacitor C6 and terminated at 75 ohms by resistor R2. It is also AC coupled into the video sync separator IC1 by capacitor C2. The LM1881 (IC1) splits this into its constituent parts, two of which, *Vertical Sync* and *Composite Sync*, are fed to the PIC (IC2) at pin 6 (RB0) and pin 8 (RB2) respectively.

As IC2 receives the Line Sync pulses it counts them, and depending upon the line number sets the two lines to the DISABLE pins (8) of IC3 and IC4. When the disable line is low, the output of the relevant video amp (IC3 or IC4) goes high impedance so blocking the input signal, while logic 1 (+5V) turns the device on and its input signal is allowed to pass through.

Video amp IC3 is configured as a x2 amplifier and IC4 is used as a unity-gain buffer switching the DC black level obtained from the voltage



The completed PIC Video Cleaner PCB is bolted to the case "lid" with small spacers between the base and underside of the circuit board. Note the "looped" supply and test point links.



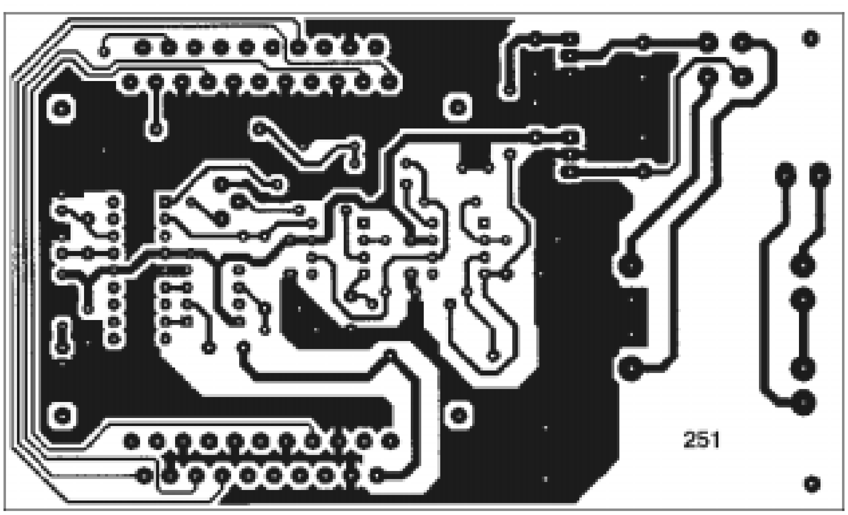


Fig.6. Printed circuit board component layout and (approximately) full-size copper foil master pattern for the PIC Video Cleaner. The SCART sockets are bolted to the PCB via small right-angle brackets.

divider network of resistor R5 and preset VR1.

Resistors R7 and R8 terminate the output of the AD810s at 75 ohms and capacitor C11 couples the output to the TV.

CONSTRUCTION

BE AWARE THAT RAW MAINS IS PRESENT ON THE BOARD. THIS MAY PROVE LETHAL IF TOUCHED!

Before undertaking any testing, take the precaution of placing insulating tape over the underside of the completed circuit board where the soldered connections protrude before handling the unit with the supply switched on.

Construction of the *PIC Video Cleaner* project is based on a single-sided printed circuit board (PCB). All the components, with the exception of the power-on light-emitting diode (LED) D1, are mounted directly on the PCB. D1 is mounted on one side of the case and short wires are soldered to it and its position on the PCB.

The printed circuit board component layout and (approximately) full-size copper foil master are shown in Fig.6. This board is available from the *EPE Online Store* (code 7000251) at **www.epemag.com**

Component placing should cause no problems. Check the orientation of the ICs and electrolytic capacitors before soldering them in place. There are a few jumper/test points and these should be left long enough to attach a 'scope or DVM. As is usual practice, start by mounting the lowest profile components first and the mains transformer last.

Do not use IC sockets for IC3 or IC4. Instead, these should be soldered *directly* to the board in order to avoid affecting the video signal due to parasitic capacitance – be as quick as possible when carrying out this operation.

The PIC IC2 and IC1 are both mounted in sockets. These sockets should be turned-pin types if possible for reliability.

The unit should be housed in a plastic case, with holes cut in it for the SCART sockets and LED. If the box suggested is used the SCART sockets will just protrude, making them easier to access when the box is assembled.

The SCART sockets are supported with metal L-shaped brackets. This helps to prevent the soldered connections failing due to stress when inserting or removing their plugs.

The circuit board is mounted with six 3mm bolts and spacers onto the bottom of the box. Using the unpopulated PCB as a drilling template will ensure correct alignment of the mounting holes.

TESTING AND SETTING UP

Having completed placing the components, check that the ICs and electrolytic capacitors are mounted correctly. Then check for short circuits on the 5V lines with a meter. If these check out apply mains to the circuit and confirm you have +5V and –5V supplies present, and nothing is getting hot.

There is only one preset, so setting up may be done "live", but you will need a second video recorder. It should not be necessary to record a tape in order to set up the *PIC Video Cleaner*. Select the video channel on the TV. Play back a good quality video tape through the video recorder and select the "AV" channel on the second recorder. This should give direct picture feed-through from SCART to SCART. Now vary VR1 until clean whites and a stable picture are obtained. This completes setting up.

Complete mounting the unit in its case, carefully pushing LED D1 into position as you close up the top and secure the mains cable.

FAULT FINDING.

If things do not work and the component placement checks out, carefully check the board for solder-whiskers or dry joints. Check that the 5V supplies are both present and correct to within ±100mV.

If these are both correct disconnect the power and remove the PIC. This allows the two disable lines to IC3 and IC4 to be connected to ground (0V) or +5V without damaging the PIC.

With IC2 removed first establish that a normal tape will play back through your TV by connecting test point TP1 to +5V and TP2 to ground (0V). Doing this turns the video signal ON, and disables the rest of the circuit.

If this works, reverse the leads and use a multimeter to check that the black level voltage is present at test point TP3 and is also enabled via IC4 on the junction of R7/R8/C11. This should vary from zero to 3·3V, as the preset is turned.

Assuming that this is correct, power down and replace IC2. If you have access

to an oscilloscope check that the 10MHz clock is running on pins 15 and 16 of IC2, and that the MCLR line, pin 4, is at +5V. The sync pulses to the PIC should be clean and the 'scope should have no trouble locking on to the VSYNC line.

Should the sync pulses appear to be unstable, having a variable length and frequency then the playback VCR is suspect. This problem would be caused by dirty or worn heads. Try using a head cleaning tape first, and if this does not correct the problem the VCR should be swapped for another, newer, one.

SOFTWARE

The software for the *PIC Video Cleaner* may be downloaded *Free* from the *EPE Online Library* at **www.epemag.com**

A ready-programmed PIC chip is also available and full details, including the above options, can be found in the *Shoptalk* page in this issue.

IN THE FUTURE

This circuit should be fairly future-proof since all the work is done by the PIC. It should only be a matter of re-writing the firmware to overcome any changes, which may come along.

My friend's son? Quite happy!

Acknowledgments

Analog Devices AD810 datasheet. Antii Paarlahti at **www.cs.tut.fi** FAQ and details of line pulses. National Semiconductor's LM1881 datasheet. This datasheet is also a useful source of information on the composition of the video signal and sync pulses.

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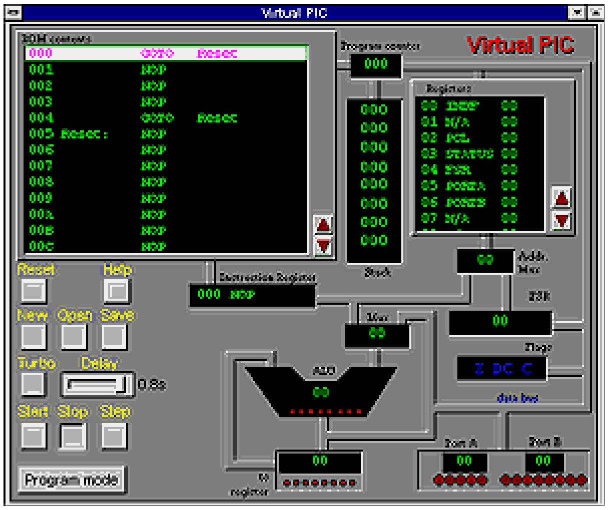
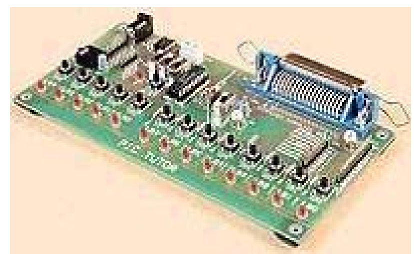
Go to next section

Interested in programming PIC microcontrollers? Learn with *PICtutor* by John Becker



This interactive presentation uses the specially developed Virtual PIC simulator to show exactly what is happening as you run, or step through, a program. In this way, the CD brings the EPE PIC Tutorial series to life and provides the easiest and best-ever introduction to this subject.

Nearly 40 tutorials cover almost every aspect of PIC programming in an easy-to-follow sequence.



Deluxe PICtutor Hardware

HARDWARE: Whilst the CD-ROM can be used on its own, the physical demonstration provided by the PICtutor development Kit, plus the ability to program and test your own PIC16x84s, really reinforces the lessons learned. The hardware will also be an invaluable development and programming tool for future work once you have mastered PIC software writing.

Two levels of PICtutor hardware are available -- Standard and Deluxe. The Standard unit comes with a battery holder, a reduced number of switches, and no displays. This version will allow you to complete 25 of the 39 tutorials -- it can be upgraded to Deluxe at a later date, by adding components, if required.

The Deluxe development kit also has a battery holder (so it can be used around the world), all switches for both PIC ports, plus LCD and 4-digit 7-segment LED displays. It allows you to program and control all functions and both ports of the PIC, and to follow all 39 tutorials on the CD-ROM.

All hardware is supplied fully built and tested and includes a PIC16F84 electrically erasable programmable microcontroller.

PRICING: **CD-ROM (Hobbyist/Student): $70 US Dollars (plus S&H)**
Standard PICtutor Development Kit: $75 US Dollars (plus S&H)
Deluxe PICtutor Development Kit: $160 US Dollars (plus S&H)

Visit the EPE Online store now to BUY!

MINIMUM SYSTEM REQUIREMENTS: PC with 486/33MHz or higher, VGA+256 colors or better, CD-ROM drive, 8MB RAM, 8MB free space on hard disk. Windows 3.1/95/98/NT, mouse.

FIND IT - DON'T LOSE IT

by TERRY DE VAUX_BALBIRNIE

Locates almost anything in the dark!

A fuse blows and the lights go out. Everything goes dark. You fumble for the torch – you know it's there somewhere – but where?

Let this little gadget show you where!

FIND IT

With the battery-powered *Find It* circuit, you will always be able to locate a torch (flashlight), bunch of keys, door lock – just about anything – in darkness!

While sufficient light reaches a sensor (light dependent resistor – LDR) on the unit, nothing happens. However, when it is dark enough, a light-emitting diode (LED) begins to flash briefly about once every five seconds. This helps to locate the item.

If preferred, you could increase or reduce the flash rate. However, any increase would reduce the life of the battery.

LIGHTING THE WAY

There are many ways of using this circuit and readers will, no doubt, have their own ideas. One method would be to attach the unit to a wall close to the object to be "found". Alternatively, a hook could be fitted to the box so that, say, a bunch of keys or a torch could be hung from it (see photograph).

It would also be possible to attach the unit to a portable item. In some cases, it might even be possible to build the circuit panel inside a piece of equipment but the reader will need to make certain that he or she is totally aware of any safety implications and must be competent at doing the job correctly.

If you are going to use the device to locate a door lock, it may be convenient to have only the LED showing next to the lock and connect it to the unit mounted on the inside of the door.

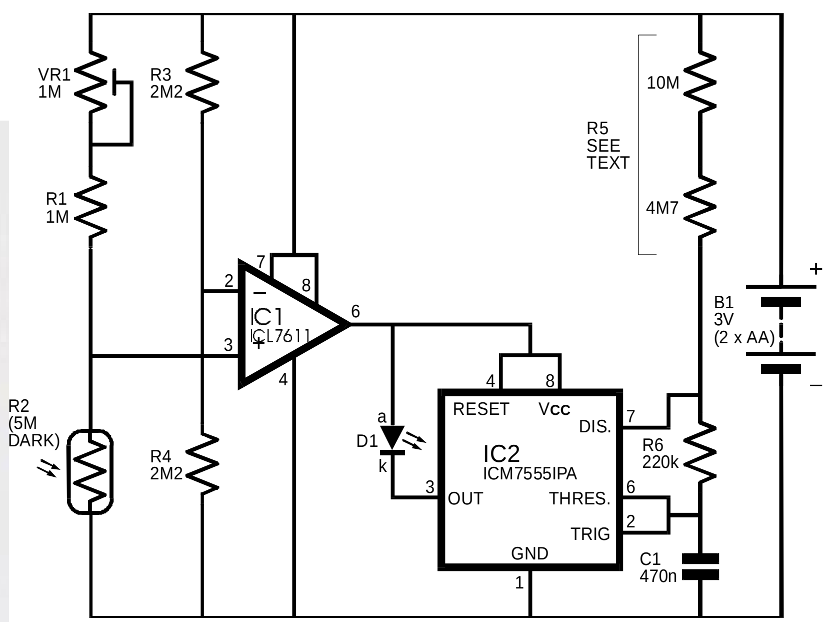


Fig.1. Complete circuit diagram for Find it. Left, Find It being used as an illuminated keyring hook.

As well as household applications, this circuit will be found handy in many outdoor pursuits. Campers and anglers will certainly find uses for it. Note that, in some cases, it will be necessary to waterproof the box and this is left up to the constructor.

The circuit draws power from two AA-size alkaline cells, which should give some one or two years of service. Since it requires more current while the LED is flashing, the actual life of the batteries will depend on the number of hours of darkness in a given 24 hour period. It also depends on what degree of illumination is set for the unit to begin operating.

While sufficient light reaches the sensor (so that the LED is off), the current requirement of the prototype circuit is only 5uA which may be regarded as negligible. While the LED is flashing, this rises to an average 250uA approximately.

This small operating current is achieved by using a short duty cycle – that is, the LED is off for much longer than it is on – about 65 times longer. Thus, in each five second cycle the LED is only actually operating for some 0·08s (80ms).

Although while glowing the LED draws about 10mA, the average requirement is therefore only 150uA approximately. This is added to the 100uA approximately required by the rest of the circuit, giving a total of 250uA. If it is assumed that there are eight hours of operation in a 24 hour period, the average overall current requirement is therefore only 80uA approximately.

While the battery voltage exceeds about 2·5V, the LED will flash brightly. It will become

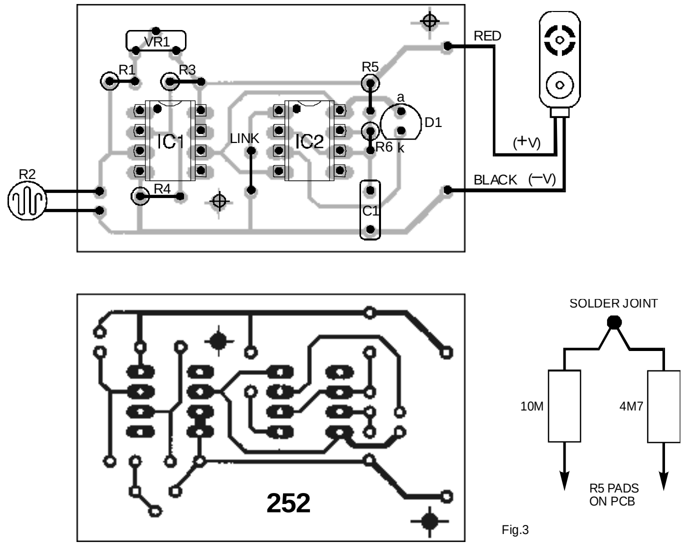


Fig.2. Printed circuit board component layout and (approximately) full size copper foil master pattern. Fig.3 (inset). How to make up R5 by wiring two resistors in series.

correspondingly dimmer down to about 2V which is the practical end point.

CIRCUIT DESCRIPTION

The complete circuit diagram for the *Find It* project is shown in Fig.1. This may be considered to comprise two sections. The first is the light sensing part based on IC1 and associated components and the second, the LED flasher centered on IC2.

Integrated circuit IC1 is an operational amplifier (opamp). This has been specially selected for its ability to operate from a low supply voltage combined with an exceptionally small standby operating current.

Looking at the light sensor stage first, the opamp inverting input (pin 2) is maintained at a voltage equal to one-half that of the supply (nominally 1·5V), due to the effect of equal value resistors R3 and R4 connected as a potential divider across the power supply. Since these have a very high resistance, the continuous current flowing through them is only a fraction of a microamp.

The opamp's non-inverting input, pin 3, is connected to a further potential divider. The top arm of this comprises preset potentiometer VR1 connected in series with fixed resistor R1. The lower one is simply light-dependent resistor (LDR) R2.

As the intensity of light reaching the LDR's sensitive surface falls, its resistance rises and so does the voltage across it and hence at the non-inverting input, pin 3. Depending on the adjustment of VR1, this voltage will exceed that at the inverting input, pin 2, at the operating light level.

A simple rule about opamps is this. When the voltage applied to the non-inverting input exceeds that at the inverting one (as will happen here in dim light), the output (pin 6) will be high. When it is less (bright light), it will be low.

The ICL7611 has an almost

COMPONENTS

Resistors
R1 1M (or as required - see text)
R2 sub-miniature light-dependent resistor (5mm diameter, 5 megohms dark - see text)
R3, R4 2M2 (2 off)
R5 14M7 (10M and 4M7 in series or as required - see text)
R6 220k
All 0.25W 5% carbon film except R2

Potentiometer
VR1 1M miniature enclosed carbon preset, vertical

Capacitor
C1 470n miniature metalized polyester - 5mm pin spacing

Semiconductors
D1 3mm red high-brightness LED (see text)
IC1 ICL7611 micopower opamp
IC2 ICM75551PA low-power CMOS timer

Miscellaneous
B1 3V battery pack (2 x AA cells with holder).

Printed circuit board available from the *EPE Online Store*, code 7000252 (**www.epemag.com**); plastic case, size 102mm x 76mm x 38mm external; 8-pin DIL socket (2 off); PP3-type battery connector (or as appropriate for the holder); connecting wire, solder, etc.

See also the SHOP TALK Page!

Approx. Cost Guidance Only (Excluding Batts) **$16**

full output swing between the supply voltage, and its output will therefore go from 0V to 3V nominal as the light level falls to the required operating point.

LIGHT FLASHER

Now let us look at the LED flasher based on IC2. This consists of an astable (free-running pulse generator). Its frequency is related to the value of resistor R5 (in the prototype, this consisted of two resistors connected in series to make up the required value), resistor R6 and capacitor C1.

The *on* times (during which the output, pin 3, is high) are provided when C1 charges through resistors R5 and R6 to two-thirds of supply voltage (2V approx.). After that, the capacitor discharges via internal circuitry through resistor R6 alone to one-third of supply voltage (1V approx.) and this gives the *off* period during which pin 3 is low.

This cycle repeats indefinitely as long as a supply exists to pin 8 and the reset input at pin 4 is high. With the values of components specified, each cycle takes about five seconds.

Since resistor R5 has a much higher value than R6, capacitor C1 charging time is much longer than the discharge time. Thus, the time during which output pin 3 is high is much greater than when it is low. If a LED was connected between pin 3 and the 0V rail, this would give the opposite effect to that which was required – it would be on for longer than it was off!

To overcome this, the current-sinking capability of IC2 is exploited. That is, current is able to flow from supply positive through the LED and *into* the output.

With the LED connected like this, current will flow through it when pin 3 is *low* rather than when it is high. The result is that the on transitions are much shorter than the off ones. Note that there is no need to use a current-limiting resistor connected in series with the LED, because the operating current is limited to a suitable level by the chip itself.

Referring back to the operation of IC1, its output (pin 6) is connected to IC2 pin 8 (supply positive) and pin 4 (reset) so, while IC1 output is high (that is, when the LDR is sufficiently dark) the criteria are met for the astable to operate and the LED flashes.

In the original version of the circuit, the LED D1 anode (a) was connected direct to supply positive so relieving IC1 of its load. However, even with IC1 pin 6 low (and so apparently no supply existing for IC2), the LED continued to flash dimly!

It seems that current sinking through the LED provided a weak supply for IC2 which allowed it to oscillate. In the final version of the circuit the anode of D1 is connected to IC1 output and this solves the above problem. When the LDR receives sufficient light, there is no power supply for IC2 and nothing happens.

Using IC1 to switch on the power supply for IC2 has a particular advantage in that IC2 draws no current at all while the LDR receives sufficient light, and this greatly reduces the standby current requirement of the circuit as a whole.

CONSTRUCTION

All components, except the cell holder, are mounted on a small single-sided printed circuit board (PCB). The topside component layout and full size underside copper foil track master are shown in Fig.2. This board is available from the *EPE Online Store* (code 7000252) at **www.epemag.com**

Begin construction by drilling the fixing holes then solder the IC sockets and single link wire in position. Do not insert the ICs themselves yet, however. Follow with all other components except the LED D1 and LDR R2.

The suggested value for resistor R5 (14·7MΩ) may be

Completed unit showing positioning of the circuit board and the two-cell holder. Note the light dependent resistor (LDR) mounted in one side panel.

made up using a 10MΩ unit connected in series with a 4·7MΩ one. These are arranged as shown in Fig.3 with the free ends soldered to the "R5" pads on the PCB.

Raising the value of the combination would reduce the flash rate and vice-versa. A 10 megohm, resistor alone would give a rate of about one flash every three seconds.

If you are using the specified miniature LDR having a "dark" resistance of about 5MΩ, then the suggested value of resistor R1 will probably be found to work well. If you use a different LDR having a lower "dark" resistance (say, the common ORP12 type), you may need to reduce the value of R1 to, say, 100kΩ.

FINAL ASSEMBLY

Hold the PCB a small distance above the base of the box and decide how long the LED and LDR leads need to be. The LED should be soldered so that its tip will eventually stand slightly higher than the face of the lid. Take care over its polarity (the slightly shorter lead is the cathode (k).

Note that the specified LED used in the prototype is the *high-brightness* type, and this was found to give better results than the standard variety. However, beware of any LED that has a narrow viewing angle. This could prevent it from being seen if the user is too far off-axis.

The LDR leads should be of such a length that its "window" will take up a position level with either the top face or side of the box depending on the layout decided on. Solder it in place using as little heat as possible to prevent possible damage.

If you wish to mount the LED remotely from the PCB, use a piece of light-duty twin-stranded wire soldered to its copper pads on the PCB. When soldering the LED to the other end, take care over the polarity.

Also, be careful to avoid short-circuits at the joints. Insulate and waterproof them as necessary using heat-shrinkable sleeving. Solder the end wires of the PP3-type battery connector (or as appropriate for the battery holder being used) to the "+V" (red) and "0V" (black) points on the PCB.

Insert the ICs, with the correct orientation, into their sockets. Since they are both CMOS components, they could possibly be damaged by static charge, which might exist on the body. It would therefore be wise to touch something which is earthed (such as a water tap) to remove any such charge before handling the pins.

TESTING

A check may be carried out before mounting the PCB in the box. In that way, any faults will be more easily rectified.

Adjust preset VR1 fully anti-clockwise (as viewed from the top edge of the PCB). This will allow the circuit to respond without having to cover the LDR completely and this will make testing easier. Insert the cells into their holder taking care with the polarity and connect it up.

With the LDR covered with the hand, the LED D1 should flash about once every five seconds. Be patient because you will have to wait longer than this for the first flash. The actual rate is not particularly important but it could be made faster or slower by reducing or increasing the value of R5 respectively.

Now, uncover the LDR so that light falls on it. The LED should stop flashing. If you find difficulty making it work, try again with the LED covered more carefully or take the unit into a dark cupboard.

Adjust VR1 so that the circuit operates at the required degree of illumination. You may

find that you need to make further small adjustments when the circuit panel is mounted in position.

BOX IT

If a hook or something similar is to be attached to the case, take account of the PCB position so that any fixings will not cause a short-circuit.

Remove the connector from the cell holder. Position the PCB on the bottom of the box and mark through the fixing holes. Remove the PCB again and drill them through.

Decide where the hole is to be drilled to allow light to reach the LDR. It must not be obscured too much during use or this would result in the LED flashing more than necessary with a consequent increase in the current requirement.

In the prototype, the LDR leads were bent through right-angles (see photograph) and the hole was made in the side of the box. However, the exact arrangements will depend on the application.

Carefully measure the positions of the LED and LDR and drill the holes for these components. The hole for the LED should be of such a diameter that its tip will protrude through it only slightly. That for the LDR should be a little smaller than its window so that this will lie just behind the hole when the PCB is in position.

If required, you could drill a small hole to allow preset VR1 to be adjusted from outside the case using a small screwdriver or trimming tool. However, this was not done in the prototype.

FINISHING OFF

Attach the PCB using plastic spacers on the bolt shanks so that the LED and LDR take up their correct positions. Attach the cell holder to the bottom of the box using a small fixing.

Secure the lid of the case taking care that the LED engages with its hole and test the circuit under real conditions. Make further adjustments to preset VR1 if necessary so that the LED begins to flash at the required light level.

Clockwise rotation of the sliding contact (as viewed from the top edge of the PCB) allows operation with less light. If you would like the LED to start flashing under dimmer conditions and this is not possible with VR1 adjusted fully clockwise, increase the value of resistor R1 – 2·2 megohms would be a good starting point.

Put the *Find It* into service. When the LED begins to flash too dimly to be seen effectively, it is time to replace the batteries.

Go to next section

Ingenuity Unlimited

ROLL-UP, ROLL-UP!

Ingenuity is our regular round-up of readers' own circuits. We pay between $16 and $80 for all material published, depending on length and technical merit. We're looking for novel applications and circuit tips, not simply mechanical or electrical ideas. Ideas must be the reader's own work **and must not have been submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should preferably be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.**

Send your circuit ideas to: Alan Winstanley, *Ingenuity Unlimited*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset BH21 1PF. They could earn you some real cash and a prize!

Win a Pico PC-Based Oscilloscope

- **50MSPS Dual Channel Storage Oscilloscope**
- **25MHz Spectrum Analyzer**
- **Multimeter**
- **Frequency Meter**
- **Signal Generator**

If you have a novel circuit idea which would be of use to other readers, then a Pico Technology PC based oscilloscope could be yours.

Every six months, Pico Technology will be awarding an ADC200-50 digital storage oscilloscope for the best IU submission. In addition, two single channel ADC-40s will be presented to the runners up.

Mini Disc Optical Interface – Link-Up

Being the proud owner of a new Mini Disc recorder, my problem was that I only had the usual line output on my hi-hi system to record from. I wanted to use the MD to its fullest extent to record digitally instead, so as not to lose any quality at all.

I found the answer in the shape of a fiber optical transmitting module for a standard optical cable (itself available in the High Street). The Toshiba TOTX176 module has its own drive circuitry for the emitter LED and can be used as an interface. A datasheet is available from the Toshiba web site at **www.toshiba.com**

In the end, the source for the digital signals was to be found on the rear of the CD ROM in my PC, not in the hi-fi system at all (see Fig.1). The connections were simple, 5V, ground and the signal wire which can be picked up from the rear of the CD ROM drive.

The Toshiba transmitter is available from Maplin, part no. SV09K, and this can be soldered to a small piece of stripboard and fitted within the PC. I used a spare drive bay blanking plate to mount the opto-emitter unit. The Mini Disc player can then be connected to the PC CD ROM drive when required. Hobbyists could experiment using old spare CD ROM drives as well.

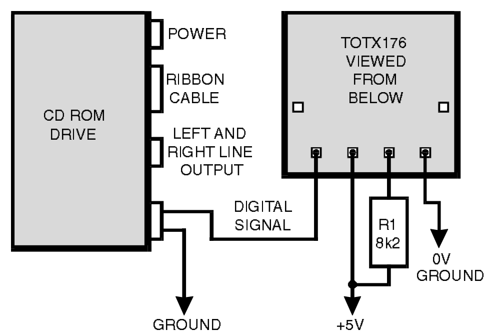


Fig.1. Mini Disk Optical Interface.

P. Mcleod
Ross on Wye, UK

VCO Generator – Sine/Square Triangle Output

The circuit diagram of Fig.2 was an attempt to produce a waveform generator using simple building blocks instead of proprietary generator chips. In the outline circuit shown, IC1a and associated parts form a switched sign amplifier.

When the MOSFET transistor TR1 is switched off, IC1a acts as a non-inverting amplifier with a gain of +1. When TR1 is on, the gain is –1. IC1b forms an integrator with resistor R5

and capacitor Cl. Its output ramps up with a negative input and down with a positive input.

The NAND gates IC2a and IC2b, along with resistors R7 and R8, form a large hysteresis Schmitt trigger, so that when the integrator ramps up to three-quarters of the total supply it switches high and when it ramps down to one-quarter it switches low. The Schmitt controls the “sign” of IC1a and thus the slope of IC1b. The triangular waveform from the integrator (IC1b) goes to IC1c, which is a simple inverting amplifier fitted with a “dead band limiter” comprising D1 and D2, two identical Zener diodes.

When the triangular waveform from the integrator exceeds the forward plus the Zener voltages (in either polarity) the gain of the amplifier is

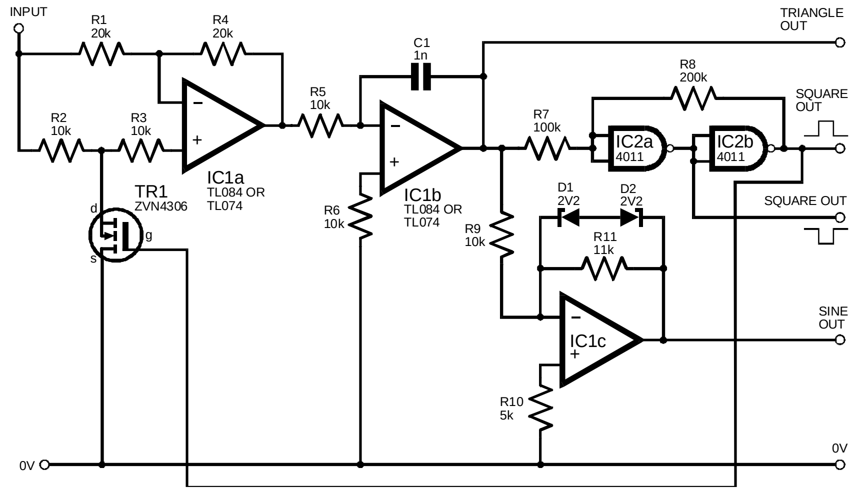


Fig.2. Circuit diagram for the VCO Waveform Generator.

reduced. This rounds off the peaks to give a fair approximation of a sinewave.

With a power supply of +6V and a Zener value of 2·2V, resistor R11 should be adjusted to give the best results. A value of 11 kilohms is about right. Both the frequency and the sensitivity are controlled by resistor R5 and capacitor C1.

A. E. Whittaker
Stone, Staffs, UK

Go to next section

New Technology Updates

IAN POOLE LOOKS AT THE LATEST DEVELOPMENTS TO IMPROVE THE LIGHT EFFICIENCY OF L.E.D.S

It is now some years since light emitting diodes (LEDs) were first available for use. Since then they have become very popular as convenient and reliable indicators.

Originally LEDs were only available in red. Now having undergone a considerable amount of development they are available in a wide variety of colors. Orange and yellow were the first to follow red, but most other colors are available, although they are slightly more expensive. Infrared emitters are also available, and these are widely used in remote controls for televisions, video recorders and a wide variety of other products that need remote control.

The cost of these indicators and displays is very low. Standard indicator lamps are available for a few pence, and high output devices are a little more. Alphanumeric displays are also very reasonably priced, making them ideal for use in home electronic products as well as many commercial ones.

BEGINNINGS

The phenomenon behind light emitting diodes was first seen many years ago. A British development engineer named H. J. Round, who was famous for many thermionic valve developments, first noticed it in 1907 when he was making some investigations into point contact crystal detectors. He reported these discoveries in *Electrical World*, although no further work was done.

The idea was not taken any further for several years, and did not surface again until it was observed by O. V. Losov in 1922. Unfortunately, he lived in Leningrad and he was killed in the Second World War when Hitler advanced on Russia. Although he published a total of four patents up until 1942, the details of his work were never discovered. However, it was Messrs. Bay and Szigeti who actually patented LEDs in 1939.

The LED resurfaced again in 1951 after the discovery of the bipolar transistor. A team of researchers led by K. Lehovac started investigations into the effect. The level of research grew rapidly and a number of companies were involved. This resulted in the first light emitting diodes being marketed in the late 1960s.

BASICS

Light emitting diodes are a specialized form of *p-n* junction. They are different from normal *p-n* junctions in that they must be fabricated from a compound semiconductor like gallium arsenide, gallium phosphide or indium phosphide. In the example of gallium arsenide, gallium has a valency of three and arsenic a valency of five and as such they are known as group III-V semiconductors. Other compound semiconductors are also formed from group III-V materials. The more common semiconductors, silicon and germanium do not emit light.

In a *p-n* junction it is found that the *p*-type region has an excess of holes and the *n*-type region an excess of electrons caused by the doping. When a forward bias is applied to the junction the electrons are attracted across the junction region into the *p*-type region. The same potential pulls the holes in the opposite direction, but across the junction. When the holes and electrons meet they start to recombine. As a result of this action a current flows across the junction.

When this occurs in an LED, energy is released, some of which is in the form of photons. Interestingly it is found that more light is usually produced from the *p*-type side of the junction, and this is kept closest to the surface of the diode to ensure that the minimum amount of light is absorbed.

To produce light of the color or correct wavelength, the correct materials must be used and the device tailored for the application. Pure gallium arsenide releases energy in the infrared portion of the spectrum. To enable light in the visible red end of the spectrum to be produced, aluminum is added to the semiconductor to give aluminum gallium arsenide (AlGaAs). Phosphorus can also be added to give red light.

For other colors other

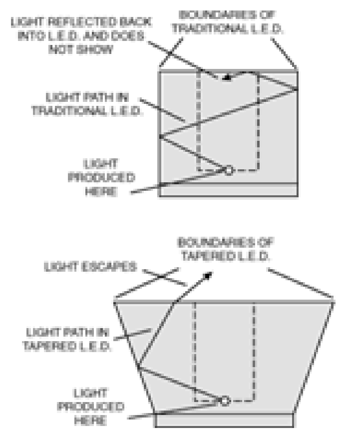


Fig.1. Light paths for traditional and new reverse tapered LEDs.

materials are used. For example gallium phosphide gives green light and aluminum indium gallium phosphide is used for yellow and orange light. Most LEDs are based on gallium semiconductors.

EFFICIENCY

One of the problems that is common to most forms of light emitter is that of efficiency. The common incandescent light bulb is notoriously inefficient, and LEDs also have a relatively low level of efficiency. Whilst this may not be a major consideration in many applications it is nevertheless a major factor in many designs, particularly those that are battery powered.

A typical LED may consume as much as 20mA and most of this is dissipated as heat. If the efficiency was improved then the current consumption could be correspondingly reduced, thereby saving battery power. As many of the ICs used in pieces equipment like cellular phones only consume a milliamp or so, and provide a large amount of functionality, this means that the proportion of current being used to give a simple indication is very high.

Over the years improvements have been made to improve the technology. As most of the light is generated at the *p*-type side of the junction, this is generally placed closer to the surface of the semiconductor so that any light that is produced has less distance to travel through the semiconductor and hence less light is absorbed.

Other techniques to improve the efficiency are also employed. Often a coating applied to the surface of the diode to match the refractive index can triple the light output, but despite this procedure a complete match cannot be obtained and it is found that only half of the internally reflected light is released.

It is also possible to encapsulate the LED in plastic that better matches the refractive indices to help reduce reflections, but this only yields a small increase in output.

NEW DEVELOPMENT

In a LED it has been found that a large proportion of the light is lost as a result of total internal reflection at the interface with the air. In a new initiative, NASA is licensing some of the fruits of its development for nominal fees and with the minimum of formalities. One of these is a structure for a LED where the level of light that is lost by internal reflection is greatly reduced.

The improvement is achieved by having a reverse taper on the semiconductor chip. This changes the direction that some of the light takes so that it strikes the air-semiconductor interface at an angle such that a greater proportion of the light is transmitted through the interface and not reflected back, see Fig.1.

The real elegance of the new idea lies in its simplicity. This makes it easy to implement and as a result it is expected that the idea will be taken up quite quickly.

With LEDs being so widely used, it is anticipated that the new LEDs will soon become commonplace, finding uses in aircraft, spatial marking lights, traffic signals, and even as night lights in homes.

Go to next section

Special Feature

TECHNOLOGY TIMELINES - Part 1

by Alvin Brown and Clive "Max" Maxfield

Boldly going behind the beyond, behind which no one has boldly gone behind, beyond, before!

Today it is difficult to imagine a world where communication between continents could take months, an incandescent light bulb could cause a crowd to gasp in awe, and the most complicated calculations were performed using only pencil and paper. By comparison, we now find ourselves in the rather strange position that a whole generation has grown up surrounded by the trappings of modern technological civilization.

This generation can barely conceive life without the near-instantaneous communication, entertainment, and data processing and presentation capabilities provided by such gadgets as radios, television, cellphones and computers.

Yet the thought of personal computers in the home was inconceivable to the vast majority of the population as little as 20 years ago. Similarly, color television was well beyond the means of most households when it was introduced a little over 40 years ago; only a tiny minority of the population had any access to a telephone just sixty years ago; and even a rudimentary radio was the privilege of the favored few only 80 years ago.

In fact the 20th Century has seen phenomenal technological progress (along with corresponding impacts on our culture). In many respects we've gone from close to nothing (technology-wise) to where we are today in the last 100 years, and many observers feel that our current accomplishments represent only the "tip of the iceberg". Thus, as we enter the 21st Century we are poised on the brink of unimaginable possibilities and potentialities. As Captain James T. Kirk would have it: *"We are boldly going behind the beyond, behind which no one has boldly gone behind, beyond, before!"*

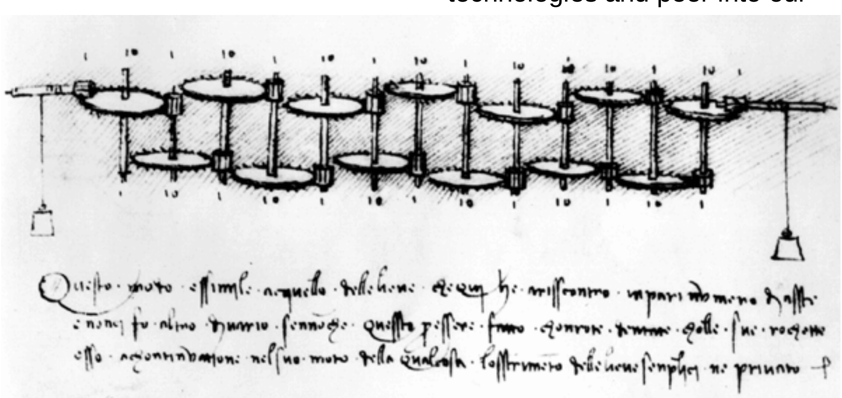
WHO, WHAT, WHEN, WHERE?

The purpose of this series is to review how we got where we are today (and where we look like ending up tomorrow). In this first installment, we shall cast our gaze into the depths of time to consider the state of the art as the world was poised to enter the 20th Century.

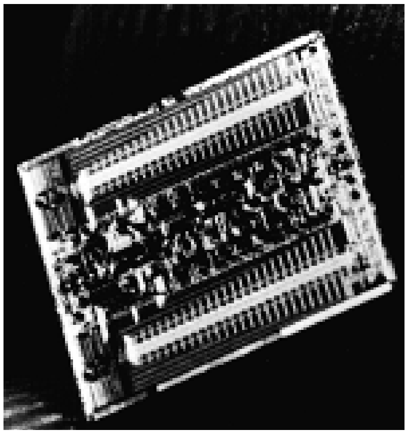
Then, over the coming months, we will take a retrospective view of the technological developments of the last millennium as we investigate the key people and events in three arenas: Fundamental Electronics, Communications, Computers.

During our discussions we shall discover the way in which everything is interrelated, such that inventions in disparate fields can be combined in ways their originators never dreamt of, catapulting us into a future none of us can conceive in our wildest dreams.

Knowing how rapidly things have changed over the last few decades, only a fool would dare to predict the future with any level of confidence. Thus, we shall leave such pontifications to the final installment, where we shall consider emerging new technologies and peer into our



The sketch in Leonardo da Vinci's notebook, which illustrates his ideas for a calculating machine, in the year 1500. Courtesy of IBM.



By complete contrast with the sketch of 1500, detail of a modern 64Kb memory chip. Courtesy of IBM.

crystal balls to cast some predictions for technological advancements in the future.

PHYSICS AND ELECTRONICS PRIOR TO 1900

Early man knew of the two major forms of electricity: static electricity and naturally occurring lightning. However, very little was understood about either of these phenomena until the 18th Century (except in generalities, such as waving a sword around during a thunderstorm wasn't a particularly good idea).

THE FIRST LIGHTNING SCIENTIST

Early cultures explained lightning in terms of myth and magic. It wasn't until 1752 that lightning's secrets began to be revealed when Benjamin Franklin performed his notorious kite experiment. Franklin tied a metal key to the end of a kite string, set the kite flying during a thunderstorm (do NOT try this at home!), and collected and stored electrical energy in a Leyden jar.

(A Leyden jar is a device that early experimenters used to store and investigate electric energy. Early implementations consisted of a cylindrical glass container with layers of metal foil on the inside and outside.)

Based on these experiments, Franklin concluded that electrical current had traveled from the storm clouds down the kite string. By this he proved that lightning was actually a natural form of electricity. (This experiment was extremely dangerous, as was demonstrated by one Professor Richman who received a more-than-bracing stroke of lightning from his apparatus.)

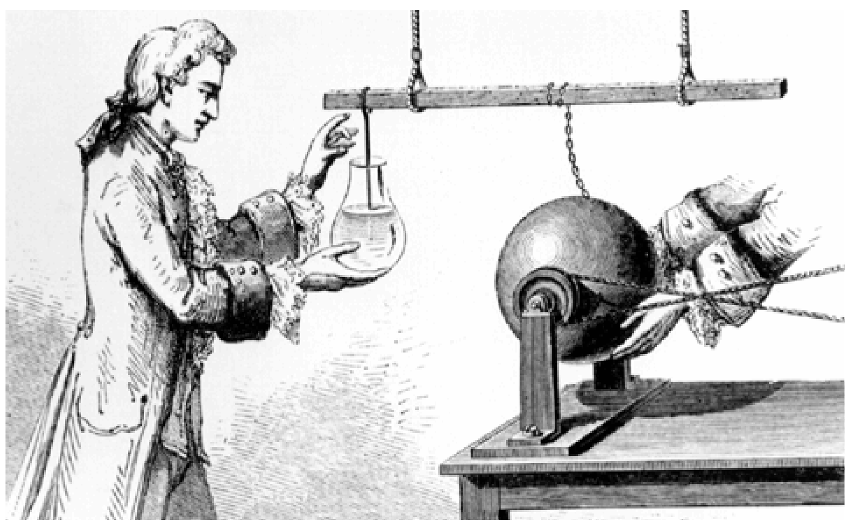
STATIC ELECTRICITY GENERATORS

The Italian Count Alessandro Giuseppe Antonio Anastasio Volta invented numerous gadgets in his lifetime, including a device based on static electricity called the *electrophorous*. This consisted of one metal plate covered with ebonite and a second metal plate with an insulated handle. When the ebonite-covered plate was rubbed, it gained a negative electric charge.

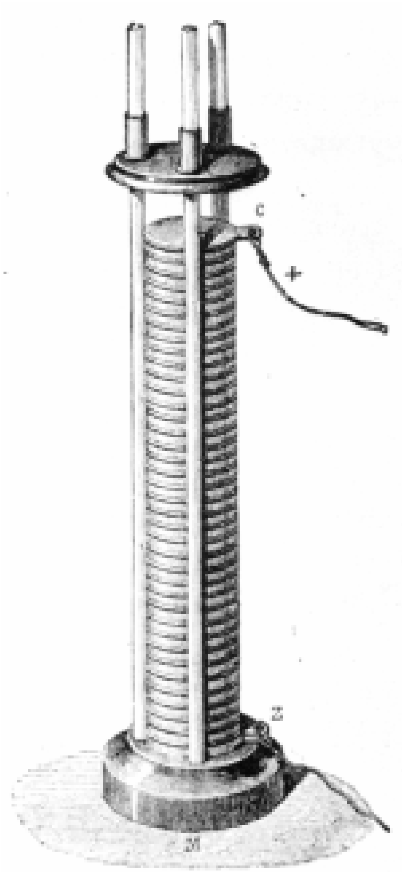
When the other plate with the handle was subsequently placed over it, a positive electric charge was attracted to its lower surface and a negative charge was repelled to the upper surface. This type of charge-accumulating device replaced earlier Leyden jars and formed the basis for the electronic components called condensers (capacitors) used today.

BATTERIES

Another of Count Volta's inventions was the electric battery in 1800. These *Voltaic accumulators* as they were known played an important part in ushering in the "era of electricity".



Historical artwork of a man (at left) holding a Leyden jar, which is being used to store electricity generated by the spherical electrostatic generator at right. The Leyden jar contains water and a brass rod. The man holding it acts as an earthed conductor. Now rarely used outside of the classroom, the Leyden jar was invented at the University of Leyden in the Netherlands in 1746. Courtesy of the Science Photo Library.



Volta's "pile" or battery of 1800. Volta (1745-1827) was a professor of physics at the University of Pavia, Italy. Courtesy of the Science Photo Library.

The first battery consisted of two bowls of salt solution that were connected by means of a metal strip dipping in the solution and connecting one bowl to the next. One end of the metal strip was made of copper, while the other was formed from tin or zinc. Volta subsequently improved on his initial design by making it less *"watery"* and more compact. He achieved this using small round plates of copper and zinc, separated by discs of cardboard moistened in salt solution. The resulting *Voltaic pile* produced a steady stream of electricity and was the forerunner of today's batteries.

The measure of electric potential was named the *Volt* in his honor.

ELECTROMAGNETICS

Following in the footsteps of Benjamin Franklin and other early scientists, the English physicist and chemist Michael Faraday was made famous by his studies of electricity and electromagnetism. In the early part of the 19th Century, Faraday discovered that electricity could be made by moving a magnet inside a wire coil. This led him to build the first electric motor, generator, and transformer.

(Around the same time that Faraday was working on his experiments, Andre Ampere was also investigating the effects of electric currents in magnetic fields, while Georg Ohm started studying the electrical resistance exhibited by different materials. Based on their work, the unit of current was called an *Amp* and the unit of resistance an *Ohm* in their honor).

Faraday introduced several words that we still use today to discuss electricity, including *anode*, *cathode*, *electrode*, and *ion*. Faraday was a great speaker and every year on Christmas Day he presented special lectures for children. The unit of capacitance (an amount of electrical charge) called the *Farad* was named in his honor, and "Faraday Lectures" are still held to this day presented by famous guest speakers.

NOTHING SUCKS LIKE A GEISSLER!

In 1855, a German glass blower named Heinrich Geissler invented a powerful vacuum

TIMELINES

1500: Italy. Leonardo da Vinci sketches details of a rudimentary mechanical calculator.

1565: The pencil is invented.

1588: The Spanish Armada comes to visit England (they were soon to regret this).

1600: John Napier invents a simple multiplication table called Napier's Bones (he also invented logarithms – 1614).

1621: William Oughtred invents the slide rule (based on John Napier's logarithms).

1623: Wilhelm Schickard invents the first mechanical calculator.

1642: Blaise Pascal invents a mechanical calculator, the Arithmetic Machine.

1671: Baron Gottfried von Leibniz invents a mechanical calculator, the Step Reckoner.

1746: Holland. Leyden jar invented.

1752: America. Benjamin Franklin performs his notorious kite experiments.

1770: The eraser is invented.

1775: Italy. Count Alessandro Giuseppe Antonio Anastasio Volta invents a static electricity generator/the electrophorous.

1800: Italy. Count Alessandro Giuseppe Antonio Anastasio Volta invents the first battery.

1801: France. Joseph-Marie Jacquard invents a loom control using punched cards.

1820: France. Andre Ampere investigates the force on an electric current in a magnetic field.

1821: England. Michael Faraday invents the first electric motor.

1821: England. Michael Faraday plots the magnetic field around a conductor.

1821: England. Sir Charles Wheat-

stone reproduces sound.

1822: England. Charles Babbage starts to build a mechanical calculating machine, the Difference Engine.

1822: France. Andre Ampere discovers that two wires with electric currents attract.

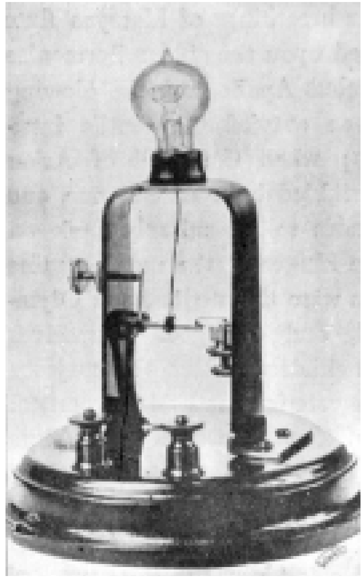
1823: England. Michael Faraday liquifies chlorine.

pump. Geissler then proceeded to use his pump to evacuate a glass tube containg electrodes to a previously unattainable vacuum. Using these *Geissler Tubes*, experimenters discovered a form of radiation, which they called *cathode rays*. These tubes, which subsequently became known as *cathode ray tubes* (CRTs), were to prove instrumental in the discovery of all sorts of things, including the electron and X-rays. Over time, CRT-based displays were to include oscilloscopes, radar screens, television sets, and computer monitors.

INCANDESCENT LIGHT BULBS

Who invented the first electric light bulb? Do we hear you cry *"The famous American Inventor, Thomas Alva Edison"*? Well it's certainly true that Edison did invent a light bulb, but he wasn't the first! In 1878, an English physicist and electrician, Sir Joseph Wilson Swan, successfully demonstrated a true incandescent bulb – a year earlier than Edison. Like Edison, Swan's light bulb employed a conducting filament mounted in a glass bulb from which air was evacuated leaving a vacuum.

In 1883, William Hammer, an engineer working for Edison, observed that he could detect electrons flowing through the vacuum from the lighted filament to a metal plate mounted inside the bulb. Although Hammer discovered this phenomena, it subsequently became known as the *Edison Effect*. As Edison later admitted, he did not even understand Ohm's law at that time. Thus, the Edison Effect remained an unexplained curiosity for fifteen years until J.J. Thompson discovered the existence of electrons. As we shall see in Part 2, the reason the Edison Effect is significant is that it was to lead to the invention of vacuum tubes.



The first electric lamp with a light bulb. It was designed by Thomas Alva Edison (1847-1931) in 1879. Edison had invested $50,000 and a year of his time to conduct 6,000 trials whilst researching a practical light bulb. Courtesy of the Science Photo Library.

CROOKES' TUBE

As the heir to a large fortune, the experimenter William Crookes had the resources to carry out scientific investigations in the comfort of his private laboratory. Following the development of the cathode ray tube, Crookes devised a series of experiments based on his own version called the *Crookes' Tube*.

By placing an obstacle, a Maltese Cross, in the path of his cathode rays and casting a shadow in the fluorescent end of the tube, Crookes demonstrated that these rays usually traveled in straight lines. Crookes also showed that the beam of cathode rays could be deflected by means of a magnet. These studies led to the discovery of the electron by J.J. Thompson in 1887. Crookes' observations of the dark space at the cathode also led to the discovery of X-rays by Wilhelm Conrad Roentgen in 1896.

DISCOVERY OF THE ELECTRON

The son of a Manchester bookseller, Joseph John (J.J.) Thompson entered college at the age of fourteen (so we can assume he wasn't a complete dingbat) and was later elected a fellow of the Royal Society and appointed to the Chair of Physics at the Cavendish Laboratory in Cambridge University.

In 1897, whilst investigating cathode rays using Geissler's tubes, J.J. Thompson made his greatest discovery. In addition to providing evidence that these rays consisted of charged particles (which J.J. called *corpuscles*, but which later became known as *electrons*), he also measured the ratio of their charge to mass and was able to show that the mass of these particles was approximately

An early ornamental Crookes' tube, with metal flowers that glowed when a current flowed.

1/1800 that of a hydrogen atom. This discovery won Thompson the Nobel Prize in 1906.

X-RAYS

In the latter part of the 19th century, the German physicist Wilhelm Conrad Roentgen discovered that some unknown radiation coming from a Crookes' Tube caused certain crystals to glow. He also discovered that this radiation (which became known as *X-rays*) could pass through solid objects and affect photographic plates. The first medical use of this discovery was an X-ray image he made of his wife's hand.

Roentgen completed his research in just eight weeks and announced his discovery to the world in 1896. The implications of his work were immediately recognized, and some hospitals began to use X-rays within a few weeks of hearing the news of his discovery. Roentgen went on to win a Nobel Prize in Physics in 1901, and his X-rays now affect most people's lives in one way or another.

TIMELINES

1827: England. Sir Charles Wheatstone constructs a microphone.

1827: Germany. Georg Ohm investigates electrical resistance and defines Ohm's Law.

1829: England. Sir Charles Wheatstone invents the concertina.

1831: England. Michael Faraday creates the first electric dynamo.

1831: England. Michael Faraday creates the first electric transformer.

1831: England. Michael Faraday discovers magnetic lines of force.

1831: England. Michael Faraday discovers that a moving magnet induces an electric current.

1831: England. Michael Faraday discovers the principle of electromagnetic induction.

1832: England. Joseph Henry discovers self-inductance.

1832: England. Charles Babbage conceives the first mechanical computer/the Analytical Engine.

1833: England. Michael Faraday defines the laws of electrolysis.

1837: America. Samuel Finley Breese Morse exhibits an electric telegraph.

1837: England. Sir Charles Wheatstone and Sir William Fothergill Cooke patent the 5-needle electric telegraph.

COMMUNICATIONS PRIOR TO 1900

The earliest form of signaling was a man running from one place to another with a verbal message. Perhaps the most famous example of this was exhibited in 490 BC, when Pheidippedes carried the news of victory at the Battle of Marathon 26 miles to Athens and then dropped down dead from exhaustion!

SMOKE AND MIRRORS

Drums and smoke signals have also been used since ancient times, along with trumpets and other audible signaling devices. In one example, chains of Roman soldiers were stationed on hilltops to shout messages to each other. Using this method it was claimed that a signal could be relayed 450 miles in 48 hours! (And if they were very lucky, the message that was received bore more than a passing resemblance to the one that had been transmitted.)

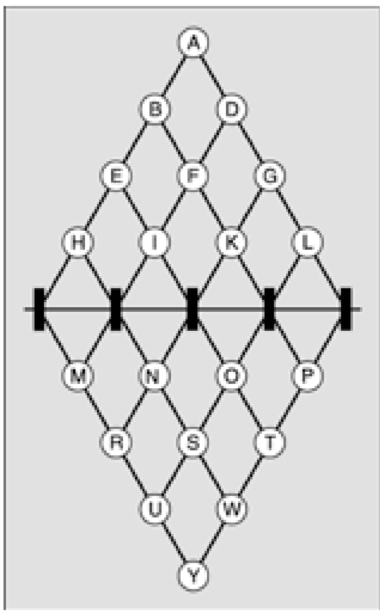
Signalers in England used beacons to send long distance messages (hence the presence of so many landmarks called "Beacon Hill" or "Signal Hill"). In fact, this method was used to send a message from Plymouth to London to communicate the approach of the Spanish Armada in 1588.

Unfortunately, these early signaling techniques were relatively slow and unreliable. In the early 1820s, scientists like Faraday and Ampere began their investigations into electromagnetics, little suspecting that their work would pave the way for much faster and more reliable communications systems in the future.

ELECTRIC TELEGRAPH

In 1837, the British physicist and Inventor Sir Charles Wheatstone teamed with his friend Sir William Fothergill Cooke to invent the first British electric telegraph (in 1829, Wheatstone had invented the concertina, so presumably he didn't have too many friends left).

Their first instrument used five wires to control five needles at the receiver, each of which could be set to one of two



The five-needle telegraph of Cooke and Wheatstone.

positions. The letters of the alphabet were laid out using a matrix arrangement, and a pair of needles could be used to point to a specific letter. Thus, messages were sent by controlling pairs of needles in sequence.

This five-needle system was replaced in 1843 with a two-needle device, which required only three wires. In this case, letters of the alphabet were identified by counting the number of deflections of the needles. This system made the news in 1845 when it was used to transmit a message about a murderer who had been seen leaving Slough, leading to his arrest at Paddington.

These systems (especially the two-needle version) became very popular in railway signaling apparatus, and in fact they can still be found in use to this day in remote parts of the globe.

In the same year that Wheatstone and Cooke were inventing their original five-needle system, the American inventor Samuel Finley Breese Morse was developing his version of a telegraph. Morse's system was based on a pattern of "dots" and "dashes" which he called Morse Code. This system enabled the transmission of a message over a single wire. The Morse Telegraph was eventually adopted as the worldwide standard, because it was easier to construct and more reliable than the British versions.

The first telegraph cable connecting England and France was laid across the English Channel in 1845. This was followed in 1858 by the first transatlantic cable linking Valentia, Ireland and Trinity Bay, Newfoundland. On the 16th of August 1858, Queen Victoria exchanged messages with President Buchanan in America. Four days later, Cunard agents in New York sent the first commercial message to report a collision between two steamships: the *Arabia* and the *Europa*.

Unfortunately, no one at that time really understood the extreme conditions that existed at the bottom of the Atlantic Ocean. The cable's insulation quickly degraded and messages became unintelligible only one

TIMELINES

1842: England. Joseph Henry discovers that an electrical spark between two conductors is able to induce magnetism in needles – this effect is detected at a distance of 30 meters.

1842: Scotland. Alexander Bain demonstrates first electromechanical means to capture, transmit, and reproduce an image.

1843: England. Augusta Ada Lovelace publishes her notes explaining the concept of a computer.

1843: England. Sir Charles Wheatstone and Sir William Fothergill Cooke patent the 2-needle electric telegraph.

1844: America. Morse Telegraph connects Washington and Baltimore.

1845: England. Michael Faraday discovers the rotation of polarized light by magnetism.

1845: England. The electronic telegraph is first used to help apprehend a criminal.

1845: England/France. First telegraph cable is laid across the English Channel.

1846: Germany. Gustav Kirchhoff defines Kirchoff's laws of electrical networks.

1847: England. Geoge Boole publishes his first ideas on symbolic logic.

1850: England. Francis Galton invents teletype printer.

1850: The paper bag is invented.

1852: France. Jean Foucault invents the first gyroscope.

1853: Scotland/Ireland. Sir Charles Tilston Bright laid the first deepwater cable between Scotland and Ireland.

1854: Crimea. Telegraph used in Crimean War.

1855: Germany. Heinrich Geissler invents a powerful vacuum pump.

1855: England. James Clerk Maxwell explains Faraday's lines of force using mathematics.

1858: Atlantic. First transatlantic telegraph cable is laid (and later fails).

1858: England. Queen Victoria exchanges transatlantic telegraph messages with President Buchanan in America.

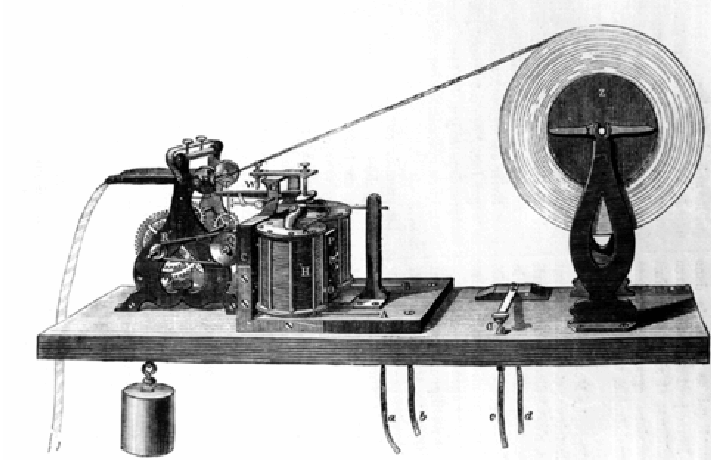
1858: America. Cunard agents in New York send first commercial telegraph message to report a collision between two steam ships.

1859: Germany. Hittorf and Plucker invent the cathode ray tube (CRT).

1865: Ireland – Newfoundland. Atlantic cable links Valentia (Ireland) and Trinity Bay (Newfoundland).

1865: England. James Clerk Maxwell predicts the existence of electromagnetic waves that travel in the same way as light.

1866: Ireland/USA. First permanent transatlantic telegraph cable is laid.



Morse code receiver. When a message was to be received, the weight (bottom left) was released turning the mechanism and feeding a strip of paper from a reel (Z). Electrical telegraph signals coming in from wires (a and b) energized electromagnets (H), which pulled down the iron or steel plate above them. By means of a pivoted lever, this raised the print head (H) which placed indentations in the paper strip which could then be read.
Courtesy of the Science Photo Library.

month after it was laid. In fact, it was almost a decade until the first permanent transatlantic link – all 1,852 nautical miles of it – was completed on 27 July 1866.

FAXING CIRCA 1842!

The first occurrence of electromechanical techniques being used to capture, transmit, and reproduce an image occurred in 1842, only five years after Queen Victoria has ascended to the throne of England, when a Scotsman called Alexander Bain came up with a rather ingenious idea.

Bain cut an image he wished to transmit out of a thin sheet of tin, which he then placed on a moving base. Above the bae was a swinging pendulum formed from a conducting wire with a pointed metal weight on the end. As the base moved slowly under the pendulum, the swinging weight periodically made contact with the metal image, thereby completing an electrical circuit. Thus, the light and dark areas of the image (represented by the presence and absence of the metal sheet) were converted into an electrical signal.

This signal was then used to control a relay moving in time with the pendulum. In turn, the relay pressed a pencil down onto a piece of paper, which was mounted on another base moving in time with the first one. Thus, the original image could be transmitted and reproduced as a pencil drawing.

TIMELINES

1872: First simultaneous transmission from both ends of a telegraph wire.

1873: England. James Clerk Maxwell describes the electromagnetic nature of light and publishes his theory of radio waves.

1874: America. Alexander Graham Bell conceives the idea of the telephone.

1875: America. Edison invents the mimeograph.

1875: England. James Clerk Maxwell states that atoms must have a structure.

1876: America. 10th March. Intelligible human speech heard over Alexander Graham Bell's telephone for the first time.

1876: America. Alexander Graham Bell patents the telephone.

1876: America. Thomas Alva Edison sets up world's first in-

dustrial laboratory at Menlo Park, New Jersey.

1877: America. Thomas Watson devised a "thumper" to alert users to incoming telephone calls.

1877: America. First commercial telephone service went into operation.

1878: America. First public long-distance telephone line between Boston and Providence becomes operational.

1878: England. Sir Joseph Wilson Swan demonstrates a true incandescent light bulb.

1878: England. William Crookes invents his version of a cathode ray tube – Crookes' Tube.

1878: Ireland. Denis Redmond demonstrates capturing an image using selenium photocells.

1879: America. Thomas Alva Edison invents an incandescent light bulb (a year after Sir Joseph Wilson Swan in England).

1879: England. William Crookes postulates that cathode rays may be negatively charged particles.

1880: America. Alexander Graham Bell patents an optical telephone system, the Photophone.

Bain had essentially created the precursor to the modern Fax (*facsimile*) machine, but his device never really caught on, because creating the image to be transmitted typically took longer than traveling to the intended recipient and drawing it out by hand!

OPTICAL TOASTERS!

The 19th century was jam-packed with weird and wonderful inventions. For example, Denis Redmond of Dublin, Ireland sent a letter to the *English Mechanic and World Science* publication in 1878. In his letter, Redmond described creating an array of selenium photocells, each of which was used to control a corresponding platinum wire. As the intensity of light on a particular photocell increased, it caused more current to flow through its associated platinum wire, which therefore glowed more brightly.

Although it only contained around 10 x 10 elements, this device could apparently represent moving silhouettes, which was pretty amazing for the time. In fact Redmond's invention is conceptually very similar to today's semiconductor diode array cameras and liquid-crystal computer screens (plus it had the advantage that you could use it to toast bread).

VICTORIAN TV?

The German inventor Paul Gottleib Nipkow proposed a novel technique for scanning, transmitting and reproducing pictures in 1884. Nipkow's technique was based on the use of flat circular disks containing holes punched in a spiral formation.

The way this worked was that a light was used to project an image onto a spinning *Nipkow Disk*. As the outermost hole on the disk traversed the image, the light passed through the hole to hit a light-sensitive phototube. The intensity of the light was modified by the light and dark areas in the image, thereby modulating the electrical signal coming out of the phototube.

The holes were arranged such that as soon as the outermost hole had exited the image the next hole began its trek. Since the holes were arranged in a spiral formation each hole traversed a different slice, or line, across the image.

At the other end of the process was a brilliant lamp and a second spinning Nipkow Disk. The electrical signal coming out of the phototube was used to modulate the lamp, which was projected onto the second disk. The modulated light passed through the holes in the second disk to construct a line-by-line display on a screen.

Although the resulting image was constructed as a series of lines, the speed of the disk combined with persistence of vision meant that an observer saw a reasonable (albeit low resolution) facsimile of the original picture. Although his system could only be used to transmit static images, Nipkow's technique was conceptually similar to modern-day television.

THE TELEPHONE

At the age of 14, the Scottish inventor Alexander Graham Bell was tremendously excited by a demonstration of a "speaking machine" created by Sir Charles Wheatstone. Bell and his older brother subsequently built their own device that emulated the human mouth, throat, tongue, and bellow-like lungs, and used it to produce human-like sounds.

Some time later, the German physicist Hermann von Helmholtz wrote a thesis stating that vowel sounds could be produced by combining the effects of electrical tuning forks and resonators. Bell heard about this paper, but due to the fact that he couldn't read German, he mistakenly believed that Helmholtz was

TIMELINES

1880: France. Edouard Eugene Desire Branly invents the Branly Coherer.

1880: France. Pierre and Jacques Curie discover piezoelectricity.

1883: America. William Hammer and Thomas Alva Edison discover the "Edison Effect".

1884: Germany. Paul Gottleib Nipkow uses spinning disks to scan/transmit and reproduce images.

1887: England. J. J. Thomson discovers the electron.

1887: England. William Crookes demonstrates that cathode rays travel in straight lines.

1887: Germany. Heinrich Hertz demonstrates the transmission/reception and reflection of radio waves.

1888: America. First coin-operated public telephone invented.

1889: America. Almon Brown Strowger invents the first automatic telephone exchange.

1890: America. Census is performed using Herman Hollerith's punched cards and automatic tabulating machines.

1892: America. First automatic telephone switchboard comes into service.

1894: England. Oliver Joseph Lodge repeats the tests of Heinrich Hertz with a modified Branly Coherer.

1894: Germany. Heinrich Hertz discovers that radio waves travel at the speed of light and can be refracted and polarized.

1894: Italy. Guglielmo Marconi invents wireless telegraphy.

1895: America. Dial telephones go into Milwaukee's city hall.

1895: Germany. Wilhelm Konrad Roentgen discovers X-rays.

1895: Russia. Alexander Popov (also Popoff) constructs a receiver for natural electrical waves and tries to detectthunderstorms.

1897: England. Guglielmo Marconi transmits a Morse Code message "let it be so" across the Bristol Channel.

1897: England. Marconi establishes the first Marconi-station at The Needles (Isle of Wight, England), sending a signal to the English coast over 22km.

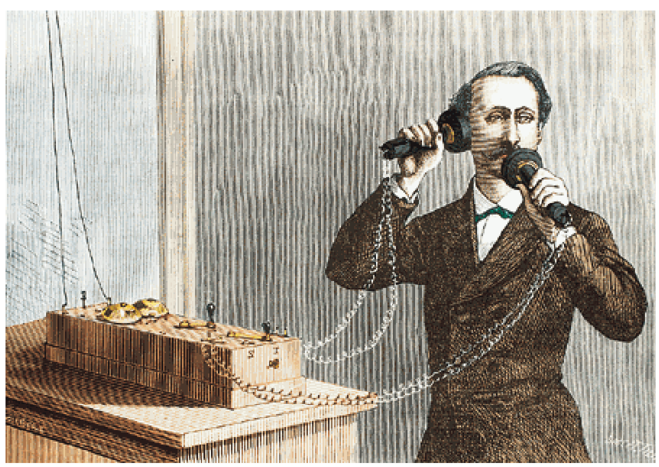
saying it would be possible to transmit sounds as electrical signals through a wire. This was to lead to what Bell would later describe as a "very valuable blunder".

Bell's interest in the spoken word continued, stimulated by the fact that his mother was deaf. The family emigrated to Canada in 1870, and a year later Bell began teaching at a school for the deaf in Boston, USA. Bell first conceived the idea of the telephone in 1874 – the same year that he met Thomas Watson – a young electrician who was to become Bell's long-time assistant.

SAVED BY THE BELL

Bell filed a patent application for the telephone on the 14th February 1876 (just a few hours before another inventor called Elisha Gray attempted to file a sort of pre-patent known as a *caveat* for a similar device). On the 10th of March, 1876, intelligible human speech was heard over the telephone for the first time when Bell spilt some acid and Watson heard him calling over their experimental apparatus saying *"Mr Watson – come here – I need you!"*

It is interesting to note that



Historical artwork of a man using a Bell telephone. In this original telephone system, the speaker and receiver were identical. This telephone was invented by Alexander graham Bell (1847-1922) who filed the patent on 14 February 1876. Courtesy of the Science Photo Library.

Guglielmo Marconi and his radio equipment, 1896.
Courtesy of Marconi PLC.

Bell's original telephone had no signaling device to let the user know when there was an incoming call. In June 1877, Watson devised a "thumper" that would strike the diaphragm of the receiving telephone box to make a tapping sound.

The first commercial telephone service went into operation in 1877. This was followed by the first long-distance line for public use between Boston and Providence in 1878. (In 1880 Bell patented an optical telephone system, which he called the *Photophone*. However, his early telephone proved to be much more practical, and optical communication systems would have to wait for another hundred years.)

WIRELESS TELEGRAPH

In 1865, the brilliant British physicist James Clerk Maxwell, a professor at Cambridge University, predicted the existence of electromagnetic waves that traveled in the same way as light. The first person to actually transmit and receive these "radio waves" in a laboratory environment was Heinrich Rudolf Hertz, a professor of physics at Karlsruhe Polytechnic in Germany.

Between 1885 and 1889, Hertz used the energy stored in large capacitors to create electric sparks, which in turn produced electromagnetic waves. He then received these waves using an aerial formed from a loop of wire with a small gap between the ends. When a large spark was generated by the transmitter, a smaller spark could be observed jumping across the gap at the receiver.

Unfortunately, Hertz died of a brain tumor at only 36 years of age without knowing for sure that it was possible to transmit and receive radio waves over large distances.

The idea that the radio waves theorized by Maxwell and demonstrated by Hertz could be used for long distance communication intrigued many physicists, scientists and inventors.

In 1880, a professor of Physics called Edouard Eugene Desire Branly at the Catholic University of Paris created the *Branly Coherer*. This was based on his discovery that loose zinc and silver filings would cling together when exposed to even a distant spark transmission field. By clinging together, the filings provided a path that exhibited increased conductivity, and this effect could be used to detect the presence of a transmission. Based on this work, the French now claim that Branly invented the wireless telegraph.

In 1894, Oliver Joseph Lodge, who held the chair in Physics at the University College in Liverpool, increased the usefulness of the Branly Coherer by adding a device that shook the fillings loose between spark receptions. Lodge's device became a standard apparatus in early wireless telegraphy. Unfortunately, after making his contribution to the world as we know it, Lodge spent the rest of his life undertaking psychic research and attempting to communicate with the dead (*"Hello Oliver, are you there?"*).

MARCONI

In reality, no one person "invented" wireless communications as we know them today. It is true that for more than 100 years Guglielmo Marconi has been called the "inventor of radio". Marconi was certainly a genius, but it's also fair to say that he built on the ideas and inventions of others (as did others).

For example, the Russian professor called Alexander Popov (also spelled "Popoff") conceived the idea of using the Branly Coherer to pick up static or atmospheric electricity, thereby allowing him to detect approaching thunderstorms (the

Guglielmo Marconi and his radio equipmenty, 1896. Courtesy Marconi PLC.

TIMELINES

1897: England. Cavandish Labs, Cambridge, J. J. Thomson uses deflection of cathode rays to measure electron charge to mass ratio.

1897: Germany. Braun improves Crookes' tube with fluorescence.

1898: 20 July. First newspaper message concerning the results of a sailing contest sent from a ship to the Daily Express in England.

1898: 3 June. First paid wireless telegram sent from The Needles (Isle of Wight/England).

1899: England. Cavandish Labs, Cambridge, J. J. Thomson measures the charge and mass of the electron.

1899: First loudspeaker is invented.

1899: England. First use of a wireless telegraph message to save lives (transmitted from the East Goodwin lightship).

precursor to the lightning detection systems we use today). Furthermore, Popov reported sending and receiving a wireless signal across a distance of 600 yards in 1895. Based on this work, the Russians now claim that Popov invented the wireless telegraph.

As an electrician in Italy, Marconi first became interested in electromagnetic radiation after reading about Hertz's experiments and Popov's ideas for storm detection. Marconi fully appreciated the possibilities of using radio waves as a means of signaling over large distances, and he patented a successful system of radio telegraphy while only 22 years of age.

Sad to relate the Italian government showed no interest in Marconi's work, so his mother (Annie Jameson of the well-known Irish Whisky family) brought him to London, where their influential relatives financed his experiments and brought him into contact with people who could help further his ambitions.

During the early years, Marconi progressively improved on the distances he could achieve with his equipment. In 1897 he managed to send the Morse Code message *"let it be so"* 8·7 miles across the Bristol Channel. And in 1899, the East Goodwin lightship used one of Marconi's wireless telegraphs to request assistance after it had been rammed in dense fog by the steam ship *M.F. Matthews*. This was the first recorded use of a wireless telegraph to save lives.

NEXT MONTH

In Part 2 of this series we'll commence by considering computing prior to 1900, followed by the development of fundamental electronics in the 20^{th} century, including the invention of the vacuum tube, the transistor, and much, much more.

Acknowledgements

We express our special thanks to IBM Archives for their supplying illustrations for this article. We also thank the Science Photo Library and Marconi PLC for their illustrations.

Go to next section

InterFACE

ROBERT PENFOLD

A 12-BIT SERIAL A/D CON-

A previous *Interface* article covered interfacing a serial analog-to-digital converter to a PC parallel port, but the original design provided only eight-bit resolution. Things move on, and chips that provide higher resolutions are available.

The chip used in the converter featured here is the AD7896AN successive approximation converter, which provides 12-bit resolution (4096 levels). It requires four lines plus a ground connection to interface to the PC, and the handshake lines of a PC printer port can provide these.

ONE AT A TIME

It should perhaps be explained that with a serial converter the data is read one bit at a time, which gives a saving of some 11 connecting wires with a 12-bit converter. Some extra lines are needed to control the chip and the flow of data, but overall there are still far less inputs and outputs used than there are bits of data.

The drawback of the serial approach is that it significantly complicates the software side of things. What would take one or two lines of code with a parallel converter can take dozens with a serial type. Reading a serial chip is also slower, although the maximum rate at which conversions can be taken is likely to be limited by the converter itself rather than the speed at which the data can be transferred.

The AD7896AN can handle up to 100,000 conversions per second, which is fast enough for most applications. However, in order to achieve this rate in practice an assembly language routine would probably have to be used to control and read the converter.

MINIMALIST CIRCUIT

The circuit diagram for the 12-bit Serial A/D Converter appears in Fig.1, and the pin functions for the 8-pin DIL version are shown in Fig.2. It will be apparent from the circuit that the AD7896AN enables a minimalist approach to be taken. In fact, the only discrete component required is supply decoupling capacitor C1. Potentiometer VR1 is simply there for test purposes, and it enables a variable 0V to 5V signal to be applied to the input at pin 1 of IC1.

Incidentally, the input voltage range of the chip is from supply rail to supply rail. There are separate analog and digital ground terminals at pin 3 and

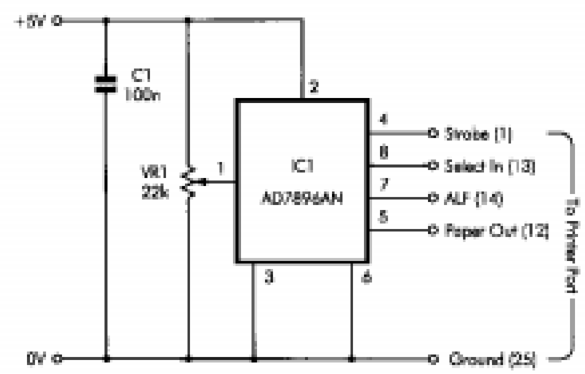


Fig.1. The complete circuit diagram for the 12-bit Serial A/D Converter.

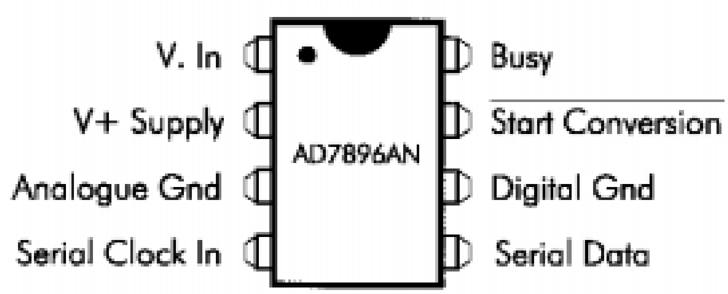


Fig.2. Pinout details and functions for the 8-pin version of the AD7896 12-bit A/D Converter.

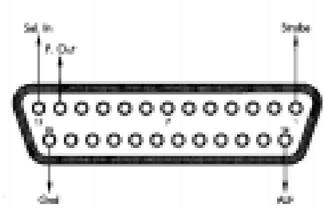


Fig.3. Details of the five connections to the Printer Port. Connections to the port are via a male 25-way D-type connector

Listing 1:Converter Program

```
unit Adconv;

interface

uses
  SysUtils, WinTypes, WinProcs, Messages,
  Classes, Graphics, Controls, Forms, Dialogs,
  ExtCtrls, StdCtrls;

type
  TForm1 = class(TForm)
    Panel1: TPanel;
    Timer1: TTimer;
    Button1: TButton;
    Button2: TButton;
    procedure Timer1Timer(Sender: TObject);
    procedure Button1Click(Sender: TObject);
    procedure Button2Click(Sender: TObject);
  private
    {  Private declarations }
  public
    {  Public declarations }
  end;

var
  Form1: TForm1;
  Prn1: Word;
  Prn2: Word;
  Prn3: Word;
  Reading: Word;
  Dta: Byte;
  Busy: Byte;
  S: String;

implementation

{ $R *.DFM}

procedure TForm1.Timer1Timer(Sender: TObject);
begin
Prn1 := 632;
Prn2 := 633;
Prn3 := 634;
Port[Prn3] := 1;
Port[Prn3] := 3;
Port[Prn3] := 1;
Repeat
Busy := Port[Prn2] AND 16;
Until Busy = 0;
Port[Prn3] := 0;
Port[Prn3] := 1;
Port[Prn3] := 0;
Port[Prn3] := 1;
Reading := 0;
Dta := Port[Prn2] AND 32;
If Dta = 32 Then Reading := 2048;
Port[Prn3] := 0;
Port[Prn3] := 1;
Dta := Port[Prn2] AND 32;
If Dta = 32 Then Reading := (Reading + 1024);
Port[Prn3] := 0;
Port[Prn3] := 1;
Dta := Port[Prn2] AND 32;
If Dta = 32 Then Reading := (Reading + 512);
Port[Prn3] := 0;
Port[Prn3] := 1;
Dta := Port[Prn2] AND 32;
If Dta = 32 Then Reading := (Reading + 256);
Port[Prn3] := 0;
Port[Prn3] := 1;
Dta := Port[Prn2] AND 32;
If Dta = 32 Then Reading := (Reading + 128);
Port[Prn3] := 0;
Port[Prn3] := 1;
Dta := Port[Prn2] AND 32;
If Dta = 32 Then Reading := (Reading + 64);
Port[Prn3] := 0;
Port[Prn3] := 1;
Dta := Port[Prn2] AND 32;
If Dta = 32 Then Reading := (Reading + 32);
Port[Prn3] := 0;
Port[Prn3] := 1;
Dta := Port[Prn2] AND 32;
If Dta = 32 Then Reading := (Reading + 16);
Port[Prn3] := 0;
Port[Prn3] := 1;
Dta := Port[Prn2] AND 32;
If Dta = 32 Then Reading := (Reading + 8);
Port[Prn3] := 0;
Port[Prn3] := 1;
Dta := Port[Prn2] AND 32;
If Dta = 32 Then Reading := (Reading + 4);
Port[Prn3] := 0;
Port[Prn3] := 1;
Dta := Port[Prn2] AND 32;
If Dta = 32 Then Reading := (Reading + 2);
Port[Prn3] := 0;
Port[Prn3] := 1;
Dta := Port[Prn2] AND 32;
If Dta = 32 Then Reading := (Reading + 1);
Str(Reading, S);
Panel1.Caption := S;
end;
```

```
procedure TForm1.Button1Click(Sender: TObject);
begin
Timer1.Enabled := False;
end;

procedure TForm1.Button2Click(Sender: TObject);
begin
Timer1.Enabled := True;
end;

end.
```

pin 6 respectively, but in normal use these are both connected to the 0V supply rail. The power consumption of the AD7896AN is very low at only about 9mW.

MAKING A START

In order to take a reading from the device, a low pulse is first applied to the *Start Conversion* input (pin 7). This activates the built-in track-and-hold circuit, and then starts the conversion process.

Data must not be read until the conversion has been completed, and one way of handling this is to use a timing loop to provide a suitable hold-off. Alternatively, the *Busy* output at pin 8 goes high during the conversion process. This output can be monitored, with a reading being taken once the *Busy* output has returned to the low state.

The data appears on pin 5, and it is clocked out by way of pin 4. New bits of data are output on pin 5 on the falling edge of the clock signal at pin 4. The reading process is therefore a matter of generating a clock pulse on pin 4, reading the state of pin 5, generating another clock pulse, reading pin 5 again, and so on until all 12 bits have been read. A software routine is used to recombine the individual bits of data into a 12-bit value. Matters are complicated

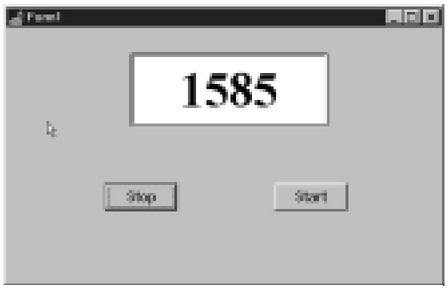


Fig.4. The converter program in action. The maximum reading is 4095.

slightly by having four leading zeros that must be clocked out before the 12 bits of data are output.

In the circuit diagram of Fig.1 the *Start Conversion* and *Serial Clock* inputs are respectively controlled by the *Auto Line Feed (ALF)* and *Strobe* handshake outputs. The *Busy* output is monitored using the *Select In* handshake input, and data is read via the *Paper Out* handshake input. The interface connects to the printer port by way of a male 25-way D-type connector, and connection details for this are provided in Fig.3.

SOFTWARE

The example program provided in *Listing 1* is for Delphi 1, and it requires a form equipped with a panel to display readings, two buttons that are used to stop and start the converter, and a timer that controls the rate at which readings are taken. With a large font selected for the panel's caption, the finished program should look something like Fig.4 when run.

The main procedure starts by setting variables Prn1, Prn2, and Prn3 at the addresses of printer port two. (Values of 888, 889, and 890 will normally be required here if the interface is used with printer port one.) The next three lines generate the start conversion pulse on the *ALF* output, and a Repeat...Until loop then monitors the *Busy* line and loops the program until it has gone low.

After the unwanted leading zeros have been clocked out the program starts to clock out and read data from the converter. The value read from the port is stored in variable *Dta*, and this value is augmented by the appropriate amount when a bit is high. For example, if the most significant bit is high, *Dta* is augmented by 2048. The value is left unaltered if a bit is at zero. Eventually all 12 bits have been read in, and the final value in *Dta* is then displayed on the panel. The stop and start buttons disable and enable the conversion process by simply switching the timer component on and off.

A 12-bit resolution gives returned values in the range 0 to 4095, and gives much better resolution than an 8-bit converter with its range of 0 to 255. In normal digital display terms it provides something between three and half and four digit resolution.

This converter should give good results in applications such as accurate temperature and voltage measurement, and future *Interface* articles will feature some practical designs based on the AD7896AN chip.

Go to next section

Circuit Surgery

by ALAN WINSTANLEY and IAN BELL

Our team of "surgeons" continue their opamp extravaganza, explaining more of the terminology used by manufacturers to describe the characteristics of operational amplifiers. We look at CMOS transmission gates too.

BISTABLE SWITCHES

Before we continue with our in-depth look at opamps, first a question from ***N. J. How*** in Malaysia about a guitar distortion pedal:

"I need to build a bistable switch, which can be used as a bypass switch for my home made guitar distortion pedal. My question is, can I use a T-type flip-flop to control a 4066 CMOS transmission gate and provide clean switching? Does the 4066 "on" resistance depend on the control voltage or perhaps the current?

I also have some noise coming out from my distortion effect. I am using a 2N3904 transistor to amplify the signal and also to produce the desired effect. Can I reduce the noise by changing this part? If I can, what transistor should I use?"

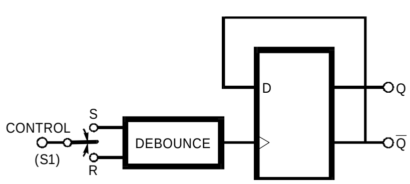


Fig.1a. A toggle-type (T-type) flip-flop can be constructed from a D-type flip-flop. S1 can be a center-off, biased switch, or a pair of momentary-action push-switches, debounced.

By "bistable switch" we assume you mean something that will alternately activate and deactivate an electronic bypass each time you press the pedal switch. Whilst you could use a suitable mechanical switch to directly bypass the distortion circuit – this would be an easy solution, and is a common approach in effects pedals – it may prove more noisy and less reliable than an electronic solution.

You are correct to suggest that a T-type flip-flop can be used to obtain bistable (push-on/push-off) control action for a logic signal from a switch. For this the switch must be a momentary action rather than a mechanical latching action. The T-type flip-flop could be implemented using a D-type with its ~Q (inverted) output connected to its D input (see Fig. 1a), with the pushswitch generating the clock pulse.

You would need to debounce the switch, which is easiest if you have a changeover switch as it can be accomplished using an SR flip-flop (or the S and R inputs of another D-type). See Fig.1b or refer to *Teach-In '98*, Part 7, May 1998, page 376, for more on switch debounce. *(This refers to the printed version of EPE, Photostats are available, Ed.)*

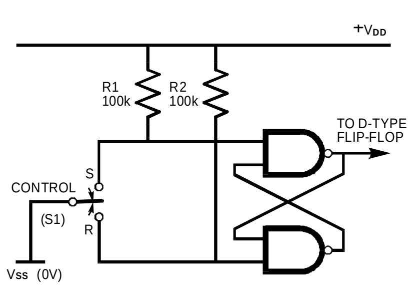


Fig.1b. A debounce circuit to toggle a T-type latch using a mechanical switch.

The output of the T-type flip-flop could certainly be used to control a 4016 or 4066-type bilateral switch (also called a transmission gate). Each gate is effectively a CMOS "switch" which can be closed using an external Enable signal: taking the Enable pin high will close the switch (On condition), see Fig.2a. When the control line is taken low, the transmission gate adopts its Off condition. Being bidirectional, transmission gates will switch both DC and AC

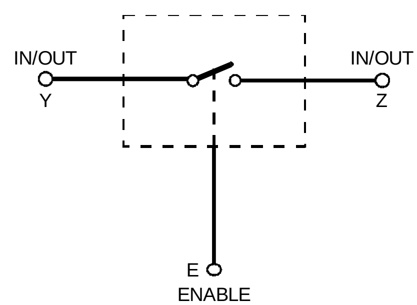


Fig.2a. A single transmission gate has a typical "On" resistance of 120 ohms.

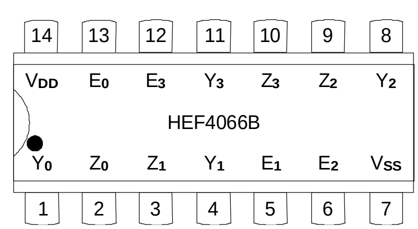


Fig.2b. Pinout details for a quad bilateral switch. IC

signals. Each 14-pin 4016 or 4066 package contains four such switches.

Data sheets on typical devices (e.g. the HEF4066B) are available from the Philips Semiconductors web site at **www-eu3.semiconductors.com/acrobat/datasheets**

The pinout details are shown in Fig.2b. These devices have many other uses, even for switching audio channels noise-free or for selecting an oscillator timing resistor using a logic circuit.

The on resistance of a 4066 depends on supply voltage, input voltage and temperature. If used correctly the control voltage should not have a large effect as it connects to a NOT gate inside the chip, rather than directly to the MOS transistors.

The internal circuitry has to provide a complementary control signal for the two complementary MOS transistors in the analog switch, so you do not get to control their gate voltages directly. As with all logic, the control input must be driven with the correct voltage levels for proper operation. The internal circuitry for both devices is published in the Philips data sheets.

A typical value for the 4066's on resistance at a supply of 10V, at room temperature, and with a full logic-level control voltage would be 120 ohms (typically varying from 100 to 120 ohms with input voltage). There are a large number of other analogue switch ICs which will give better performance than the 4066, but for a higher price than the 40p (UK pence) you might pay for a 4066.

On resistances as low as 10 ohms are available, but 20 to 90 ohms is more typical for basic switches, and more complex devices often have larger on resistances. Note that the pin-compatible 4016 has a higher on resistance than the 4066.

In addition to on resistance, the many parameters that might be of interest to the user of analogue switches include signal range, on resistance matching and cross-talk of multiple switches, leakage current, noise, distortion, bandwidth, charge injection and logic compatibility of the control inputs. Different devices may provide the best performance in one or more of these categories.

You also get a variety of switch configurations to choose from, from basic s.p.s.t./s.p.d.t (single pole single throw / single pole double throw) switches with either normally open or closed "contacts" to multiplexers and crosspoint switches. The RS Components catalog (also see **http://rswww.com**), for example, lists over 60 analog switch and multiplexer ICs, so there are plenty to choose from. Prices vary from a couple of UK Pounds for a basic switch to 20 UK Pounds for a high performance multiplexer.

MAKING A NOISE

Returning to the reader's second query, the "noise" problem is difficult to diagnose without a lot more information. All electronic components generate noise, which depends on factors such as temperature, applied voltages and operational modes (for example diodes are noisy in reverse breakdown). Sometimes, individual devices may be excessively noisy due to the presence of defects. It is possible that the transistor is the source of the noise, but it may be due to the circuit design, or the individual transistor, rather than a general property of the 2N3904. Note that the 2N3904 (an *npn* bipolar junction transistor) is actually optimized for *switching*, rather than *audio* applications, so one may find a better device, however a distortion pedal is not a conventional audio application – great care is usually taken avoid it! You can get transistors that are targeted at low-noise audio applications, for example BC184L and BC549 (or e.g. the 2N5210 according to *Towers' International Transistor Selector*). *IMB*

OPAMPS CONTINUED

Following on from our item in the Dec. '99 and Jan. 2000 issues, we have more space this month to describe further operating characteristics of opamps. You will often see the following expressions used in data sheets or catalogues and they can be used to distinguish between different opamps, so that the most appropriate device can be selected.

Supply Current Used and Maximum Supply Current – The current into +VCC or +VDD supply terminal under specified conditions.

As with power dissipation, you need to distinguish between figures for typical, maximum and quiescent (no signal) conditions. Supply current is important in low power applications (e.g. battery powered circuits).

Again, as with power dissipation, low operational

supply current is often quoted as the selling point of micropower opamps – typical values are tens of microamps (uA) or less, compared with hundreds of microamps to milliamps for normal opamps. Some low-power devices have a shutdown control that stops operation and reduces supply current to very low levels.

Output Short Circuit Duration – The length of time the output can be shorted to ground (0V), or the supplies, without causing damage to the opamp.

For many devices this is infinity due to the inclusion of short circuit protection circuitry inside the opamp.

Maximum Peak-to-Peak Output Swing – The maximum peak-to-peak output voltage that can be obtained without clipping the waveform due to saturation.

For many devices this is very close to the power supply voltages. This only applies at low frequencies, where the maximum undistorted output signal is said to be *power-supply limited*, see Fig. 3. At higher frequencies the opamp can still produce these voltages, but distortion occurs as it cannot change the output fast enough (see *Slew Rate* later).

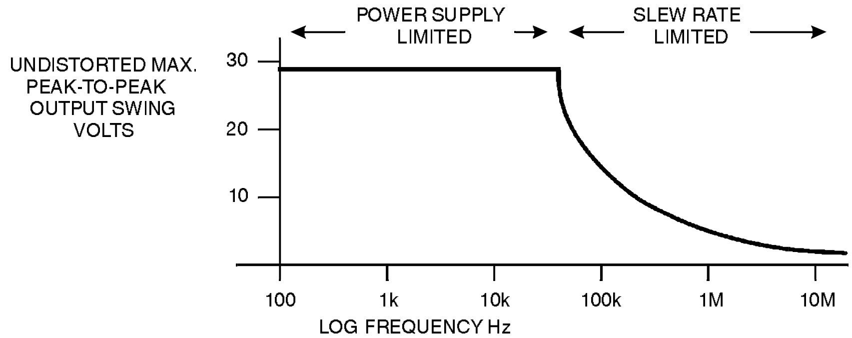


Fig.3. Graph showing the maximum undistorted peak-to-peak output amplitude for a sinewave from a typical general purpose opamp operating on a ±15V supply (actual figures would depend on the device and supply voltage used). Note the relatively low frequency at which maximum output can be produced. Higher speed opamps would give better performance in this respect.

SIGNAL HANDLING

Large Signal Gain (A) or Open Loop Voltage Gain – This is ideally infinite. In real discrete opamps it typically ranges from tens of thousands to millions. For opamps within larger integrated circuits lower gain opamps may be used where they are suitable and provide savings over using higher performance circuits.

The gain specified on data sheets is for low frequency operation and opamp gain is deliberately made to fall as frequency increases, in order to prevent instability. As we noted previously, the very high gain means that the differential input voltage in normal operation is very small (see Fig.3 in Dec. '99 *Circuit Surgery*).

Gain may be specified as a simple number e.g. 100,000, as a ratio of voltages e.g. 100V/mV, or in decibels, e.g. 100dB (in these three examples the gain is the same). The gain in decibels is found by taking the gain as a number, taking the logarithm and multiplying by 20, e.g. 100dB = 20log(100,000).

Although in some cases opamps with particularly high gains may be preferable, the precise value of the gain for *individual* opamps of a given type does not usually matter. This is because opamps are often used with negative feedback in circuits, in which the *gain of the circuit* depends on the external components and not on the gain of the opamp – it just has to be large! This means that the fall in gain of the *opamp* with frequency mentioned above does not affect the circuit until the very high frequencies at which the opamp's gain reduces.

Common Mode Rejection Ratio (CMRR) – This is the ability to reject signals common to both inputs (remember that the opamp is a *differential* amplifier, so it should ignore signals which are the same on both inputs).

Signals which are the same on both inputs are called *common-mode* signals – the common mode input voltage (CMV) is the average of the two input voltages, i.e. (V2 + V1)/2. Ideally, a change in CMV should not affect the output, but in practice it does (the ratio of output and common mode input is called *common mode gain, ACM).*

CMRR affects gain accuracy in some configurations and determines the ability of the opamp to ignore noise common to both inputs. This is

particularly important in "instrumentation" applications, where very small differential signals from sensors must be amplified in the presence of noise. Special instrumentation amplifier chips are available for this purpose. CMMR is measured in dB, 80dB to 100dB is fairly typical, but lower and higher values occur.

Unity Gain Bandwidth (fu) or Gain Bandwidth Product (GBW) – The range of frequencies for which open loop gain is greater than one.

Typical values for general-purpose devices are in the range of tens of kilohertz to a few megahertz, but may be higher – into the gigahertz range for special high frequency/high speed devices.

Slew Rate – Maximum rate of change of output (closed loop).

Slew rates are often quoted in volts per microsecond. For example, a value of 2V/us would mean that the time that the opamp's output took to change from 0V to 5V due to a step change at the inputs would be 2·5us.

Typical slew rates for general-purpose devices are from a few hundred millivolts to a few volts per microsecond, but much faster devices are available with slew rates of hundreds or thousands of volts per microsecond. A fast device with a slew rate of 1200V/us could change its output from 0V to 5V in 4·2ns.

The easiest way to think about slew rate is in terms of the response time to step change, as illustrated by the above examples. However, slew rate also determines the maximum peak-to-peak undistorted output for any type of waveform, including pure sine waves. At lower frequencies the maximum undistorted output is usually determined by the power supply voltage, but as frequency increases the opamp's output cannot move fast enough to "follow the shape" of large amplitude waveforms (see Fig. 3).

If the required peak output voltage is V_m and the slew rate is S (in volts per second) the maximum frequency sinewave that can be output without distortion is:

$$f = S / (2 \times Pi \times V_m)$$

For example for 2V/us and 15V this is 21kHz, not a particularly high frequency. In this respect low slew rate can be the significant limiting factor with some well-known general-purpose opamps such as the 741.

Supply Voltage Rejection Ratio (or power supply sensitivity) – The ability to prevent changes in supply voltage from causing changes in the output voltage.

Changes in supply current due to activities of loads or other parts of the circuit cause changes in supply voltage (the supply and its wiring have non-zero resistance). This is measured in decibels and defined in a similar way to CMRR.

Input Resistance/Impedance – *Common-Mode Input Impedance* is the effective impedance from either input terminal to ground and is ideally infinite. *Differential Input Impedance* is apparent impedance between the inputs (also ideally infinite).

The input impedances will take the form of capacitance in parallel with resistance. Sometimes the capacitance is not considered and only resistance is quoted. Input capacitances may also be quoted separately. Field effect transistor (FET)-input opamps have a particularly high input resistance (e.g. 10^{12} ohms).

Input impedance, however, is often not the main concern as the effective input impedance is increased by the use of negative feedback amplifier configurations. It is therefore bias currents which are often more important.

OFFSETS

Input Offset Voltage (V_{IO}) – Ideally with a differential input of zero the opamp's output should be zero, but in real opamps there will typically be a non-zero output.

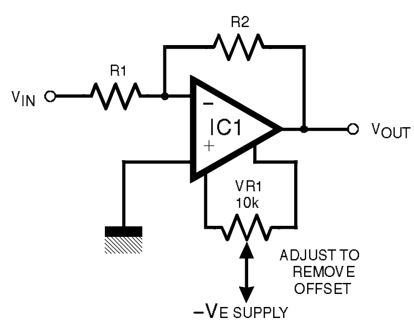


Fig.4. Typical Offset Null circuit.

The *offset* voltage is defined as the DC voltage which must be supplied between the inputs to force the quiescent (zero input voltage) open-loop (no feedback resistors) output voltage to zero. This can be regarded as DC noise in any opamp circuit processing DC signals (as many opamp circuits do).

The offset cannot be

distinguished from the wanted signal and is processed by the circuit. The offset is typically small, but will be amplified by the circuit and may cause significant problems. In opamp applications in which only AC signals are of interest offsets are less likely to be a problem as they simply cause a shift in operating point.

Some opamps have offset adjustment circuits that allow an external trimmer potentiometer, connected to the appropriate pins, to be used to set the output voltage to zero, see Fig.4. The problem with this approach is that offsets can drift with time and are quite temperature sensitive. Low offset opamps must be used in circuits where DC accuracy is required.

Bias currents flow in the external components connected to the opamp (e.g. the resistors used to set the gain) and in doing so cause voltage drops. If these voltage drops are not equal at the opamp's two inputs the difference will be amplified by the opamp and appear as a DC error at the output.

Adding a resistor to one of the inputs to balance the resistance through which the bias current flows can minimize this effect. This is illustrated in Fig.5. The bias current to the inverting input flows through R1 or R2, so making R3 equal to the parallel combination of R1 and R2 will result in the same voltage at the two inputs *due to the bias currents* (assuming the

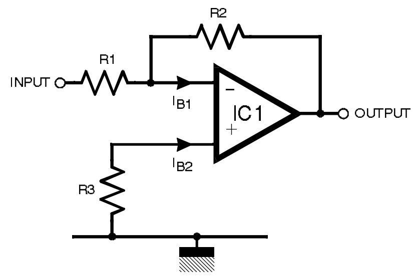


Fig.5. Resistor R3 balances the resistance seen by the two bias currents in order to reduce the offset caused by voltage drops due to the bias currents flowing in the external components.

bias currents are equal).

Temperature Coefficient of Input Offset Voltage – Specifies how V_{IO} changes with temperature. As we noted above, offset changes with temperature and this parameter tells you by how much.

Input Bias Current (I_{IB}) – Bipolar opamps require bias (base) currents for the transistors connected to their inputs, and opamps with FET inputs have leakage currents at the inputs.

The input bias current tells you how large these currents are, and is defined as the average current into the two inputs with the output at zero volts. This can vary greatly for different types of opamp, from femtoamps (10^{-15} A) to tens of microamps, with bipolar opamps having larger input bias currents than FET-input opamps.

Input Offset Current (I_{IO}) – The difference between the currents into the two inputs with output at zero volts, i.e. ($I_{B1} – I_{B2}$) where I_{B1} and I_{B2} are the input currents for the two inputs (Fig.5).

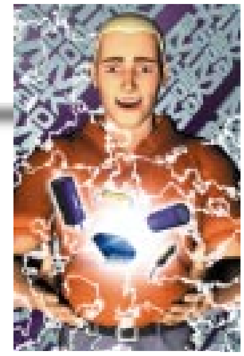
Ideally these currents will be equal, but in practice they are not, so I_{IO} will be non-zero. The input currents have to flow through the external circuitry and will cause offsets, even if the impedances connected to the two inputs are equal.

Temperature Coefficient of Input Offset Current – Specifies how I_{IO} changes with temperature.

In next month's *Circuit Surgery* we will be describing the internal aspects of opamps, and offering a selector chart of popular types. *IMB*

Go to next section

TEACH-IN 2000



PART 4 – Diodes and LEDs

by John Becker

What we are doing during this 10-part Teach-In 2000 series is to lead you through the fascinating maze of what electronics is all about! We are assuming that you know nothing about the subject, and are taking individual components and concepts in simple steps and showing you, with lots of examples, what you can achieve, and without it taxing your brain too much!

Through these simple steps we hope to prove to you that using electronic components need not be a complex task and that, providing you think about each stage of what you are trying to create, you can actually design and build something that works!

Last month we introduced color codes and resistors. We now look at capacitors and show you some of the things they can achieve when used with resistors.

There is a simpler way to generate a square wave frequency than you have been using in Parts 2 and 3, and it uses just one inverter of a 74HC14 Schmitt trigger integrated circuit (IC). Modify the breadboard layout of Fig.3.17 last month so that it looks like that in Fig.4.1, but, for the moment leave out the components numbered D2 and D3, and put a 1kΩ resistor (R1) in position D3. (See also Panel 4.4).

The assembly should be at the far left of the breadboard as other circuits will be added later, follow the breadboard numbers shown. Use the same component

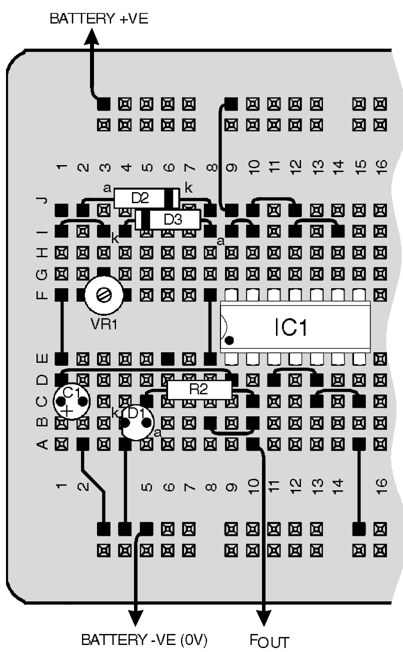


Fig.4.1. Breadboard layout for the circuit in

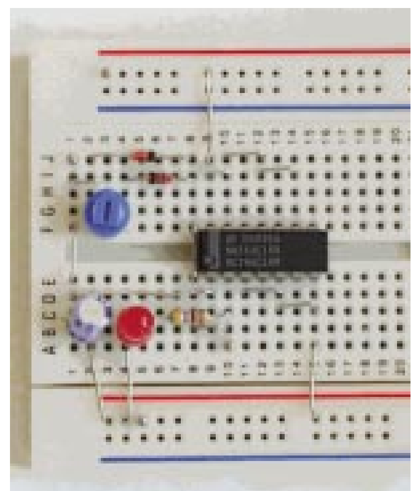


Photo 4.1. The breadboard assembly for Fig.4.1 and

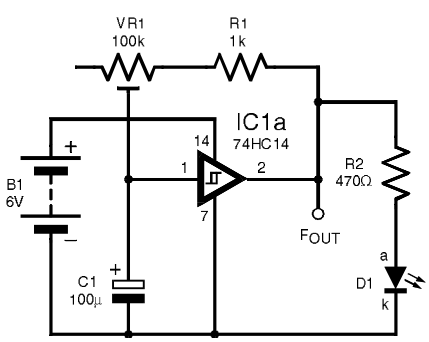


Fig.4.2. Schmitt trigger-based oscillator circuit, with square wave output.

values as shown in Fig.4.2, the circuit diagram for the oscillator as now required.

Power up the circuit and variously adjust VR1 to prove that the rate at which light emitting diode (LED) D1 flashes is just as controllable as with the oscillator in the layout of Part 3 Fig.3.1. It is important to note

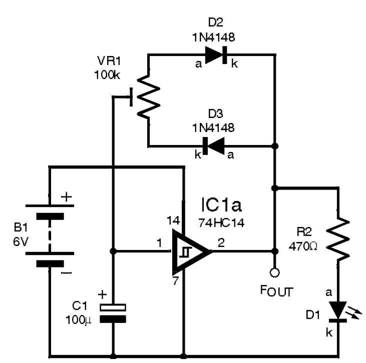


Fig.4.3. Schmitt trigger-based oscillator circuit with variable mark-space ratio control.

that this oscillator will only function with a Schmitt trigger inverter (such as the 74HC14 you are using here). A "normal" inverter, such as the 74HC04, will not work in this circuit.

Confirm that at slower oscillation rates it is obvious that the LED is turned on for the same length of time as it is turned off. In other words, that the circuit has a square wave output.

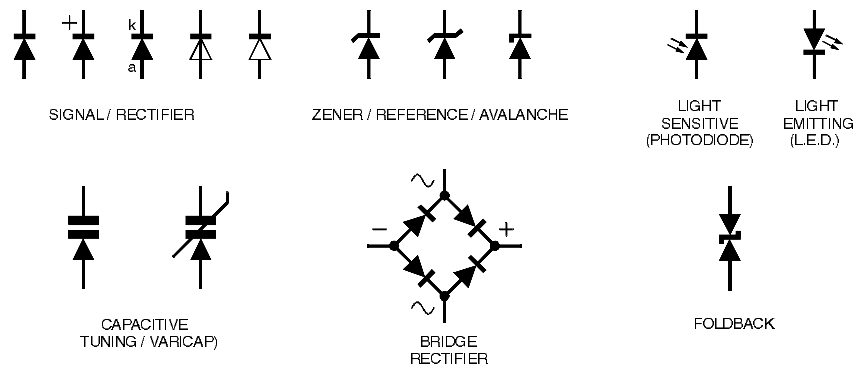


Fig.4.4. Commonly encountered circuit diagram symbols for various diode types, note that they may sometimes be enclosed in circles.

VARIABLE WAVEFORM

Now modify the breadboard to include the components numbered D2 and D3 (see Photo 4.1). The equivalent circuit diagram is shown in Fig.4.3. Remove the resistor you put in the D3 position.

Components D2 and D3 are ordinary silicon diodes of type 1N4148. We shall discuss diodes once you've discovered what they can do for an oscillator circuit.

The 1N4148 diodes in your component pack should be of about the same size and shape as the resistors you have been using. They are likely to have their identity coded on them using colored bands, in resistor fashion. The code, read from left to right, should be yellow, brown, yellow, gray, meaning, of course, 4148 (as we know from previous installments). The yellow banded end should be placed in the breadboard to correspond with the letter *k* shown on the layout in Fig.4.1 (we shall explain later what the *k* means in this context).

Again, power up the circuit and variously adjust VR1 and observe what happens to the period for which the LED is on compared to that during which it is turned off. What you will observe is that you are able to modify the oscillator's periods of relative on-offness. In other words, you can change its mark-space ratio, where "mark" means "on" (logic 1) and "space" means "off" (logic 0).

With your meter, also monitor IC1a pin 1 and note the way in which the voltage changes there. You should find that the relative rates at which the voltage rises and falls are variable.

To understand why the diodes should be having this effect, it is necessary to look at the basic nature of a diode (we gave a clue when we said in Part 1 that a LED will only function if connected to a power supply the "correct" way round). So let's fill in a few more details about diodes, including LEDs.

DIODES IN GENERAL

We shall only consider the simple points about diodes in this *Tutorial*. A full understanding of their nature and why they work requires a knowledge of atomic physics which, as we said in Part 3, we are not going discuss (sorry to disappoint you!).

You do not need to understand the physics in order to know how to use diodes, whatever the type – and there are many of them.

We aim to eventually explain all terms that you encounter in this *Tutorial*, some of which are likely to be unfamiliar to you, but some explanations might have to wait until later parts of *Teach-In*. Be patient, and read back on this section at a later date when you have gained more information.

SIMPLEST SEMICONDUCTOR

Commonly encountered circuit diagram symbols for various members of the diode family are shown in Fig.4.4.

Diodes are the simplest form of usefully processed semiconductor, involving a single junction of a p-type and an n-type material, terms which are discussed more fully when we talk about transistors in a later installment. A suitably processed semiconductor, within certain limits "designed-into" it during manufacture, has the property of being able to conduct electrical current in one direction only.

This does not mean, for example, that it conducts in a left-to-right direction, or even north-to-south. It means that the polarity of the voltage applied across its junction determines whether or not current will be conducted through it.

PANEL 4.1 – FORWARD AND REVERSE VOLTAGE

There are two principal materials from which diodes (except LEDs) are made, germanium and silicon, the latter being the more common. Other materials, such as gallium arsenide (GaAs), for example, are also used to suit different application requirements (such as LEDs).

In terms of signal direction routing, there is no basic difference between the materials. However, there is a difference in a property, which, in some respects, is undesirable in a diode, the so-called forward voltage drop. No diode conducts the full voltage level present at its anode through to its cathode; there is always a voltage drop between the two (although the output voltage will never be lower than the reference voltage of the circuit to which the cathode is connected – see the Diode Program discussion).

For germanium diodes, this drop is typically a minimum of about 0·2 volts, whereas for silicon it is typically a minimum of about 0·7 volts, although for both types the actual drop depends on several factors, which include the current flowing through it, the nature of the material from which the diode is fabricated and even its temperature. Manufacturer's data sheets state the voltage drop to be expected from a particular diode type in given circumstances.

In many instances, the higher voltage drop occurring across a silicon diode is unimportant, although for some functions the lower voltage drop across a germanium diode may be preferable. A big advantage of silicon diodes is that they can conduct higher voltages and currents than their germanium counterparts (germanium is also less plentiful and more expensive).

Although it has been said that a diode only conducts in one direction, this is not true in all circumstances. There is a limit to the amount of voltage that a diode can withstand in the opposite (cathode to anode) direction. This is known as the reverse voltage, or breakdown voltage, and varies with different types of diode construction.

Above this voltage, the diode's polarized structure breaks down and current will indeed flow back through it, often with disastrous consequences for the diode and, perhaps, other components within the circuit; diode specification parameters should never be exceeded.

Conventionally, a simple semiconducting material is regarded as having two sides, respectively called the anode, denoted by the letter *a*, and the cathode, denoted by the letter *k*. You will have seen these letters alongside the LEDs. shown in the circuit diagrams from Part 2 onwards.

In this simplest of construction, the semiconductor is known as a diode. The term dates back into history when the thermionic valve was first introduced and means "two electrodes".

If a voltage is connected across a diode with its positive side on the anode and the negative side on the cathode, a current will flow through the diode. If, on the other hand, the voltage polarity is reversed, virtually no current will flow through the diode.

It is this property that is exploited to make other derivative devices, which are known by the general name of semiconductors, i.e. transistors, integrated circuits, etc.

DIODE PROGRAM

Amongst your suite of *Teach-In* programs (which can be downloaded for Free from the EPE Online Library at **www.epemag.com**) is an interactive illustration of how a diode responds to different input voltages. From the main menu select *Simple Diode*.

On entry to the program you will see a sinewave on the left and another waveform on the right (see Photo 4.2). They represent the signal voltage before and after it has passed through the diode.

In the center is a circuit diagram showing the symbol for a simple diode. Note its anode (*a*) and cathode (*k*) markings. For the calculations in this display the diode is assumed to be manufactured from silicon. Resistor R represents the load (circuit) to which the output of the diode is connected.

The input voltage waveform is seen to be regularly oscillating between 0V and +2V. The output waveform, however, will be seen to vary only between 0V and 1·3V, with a considerable period at which it remains at 0V.

VOLTAGE DROP

One important fact to learn about any diode is that it always causes a voltage drop in any signal that passes through it from the anode (*a*) to the cathode (*k*). The term given to

this characteristic is forward voltage drop and is explained in Panel 4.1.

What you see on the screen in the output voltage graph is the input voltage level minus 0·7V drop for a silicon diode. But, because the diode only conducts in the forward direction (*a* to *k*) the output voltage can never go below the output reference voltage (in this case 0V) to which its cathode is connected via the load, hence the misshapen 0V to 1·3V waveform.

It is important to note, though, that if the output reference voltage via the load is other than 0V, then the diode's output voltage will never go below that level. For example, if the load were to be connected to 1·0V rather than 0V, then the output waveform now on screen would be swinging between 1·0V and 1·3V. Similarly, if the output reference voltage from the diode were to be –1·0V then the output voltage would swing between –0·7V and 1·3V without distortion at its lowest point.

You can explore the way in which the diode simulation responds by shifting the range of the input voltage waveform using the up/down arrow keys, and changing the load's reference voltage using the <+> and <–> keys.

DIODE FAMILY

Diodes as a family have valuable uses in their own right and, by suitably doctoring the material from which they are made (manufacturers "contaminate" – or "dope" – semiconductors with other materials in order to change their characteristics), they can

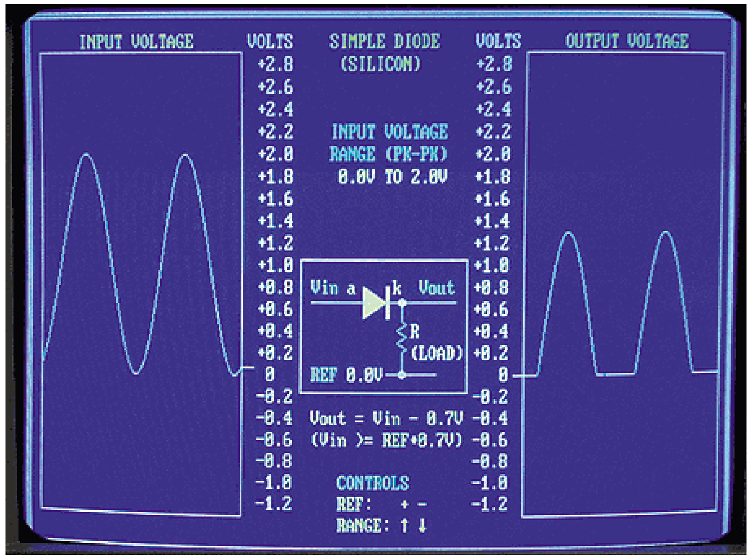


Photo 4.2. The interactive computer display illustrating how a simple diode responds to different voltage levels.

be made to do more than just conduct in a single direction.

Simple diodes, such as the type illustrated in the computer program, have just one basic function, to allow a voltage to reach one part of a circuit but prevent the voltage from that part reaching back into the circuit preceding the diode.

This function can be used, for example, to allow only the positive level of an alternating (AC) voltage to be fed forwards through the diode whilst preventing the negative level from flowing backwards through it (as the program shows).

Such an action allows the AC signal from a transformer, for instance, to be rectified (explained in a later *Teach-In* part) to produce a DC voltage, which in turn can be smoothed using a capacitor, so providing power to an entire circuit.

By its very nature, any simple diode can rectify an AC signal so that only one half of its waveform is allowed through as a polarized voltage. It can be used in either direction, depending on whether the positive-going or negative-going aspect of the waveform is required.

However, diodes are manufactured for specifically different types of rectification and other uni-directional signal flow requirements. Some, for example, may be stated as being signal diodes and are only intended for use where the voltage and current flow are small, such as the 1N4148 you've been using.

Others may be stated as being rectifier types, and these are generally more robust, being capable of handling high voltages and large currents. The 1N4001 device in your components bag (see the **Shop Talk** page in this issue of the magazine if you've only just joined us) is one of these types, it can withstand reverse voltages of about 50V and allows a forward current of about 1A (whereas a 1N4148 has respective limits of 75V and 10mA).

PANEL 4.2 – DIODE PARAMETERS, IDENTITIES, AND POLARITY

The important parameters which are usually quoted for any diode type include the following:

o) Type – e.g. germanium or silicon
o) Application – e.g. signal, rectifier or general purpose
o) PIV – peak inverse (reverse) voltage
o) IF(max) – forward maximum current

Other diode parameters may be quoted in data tables and indicated by various abbreviations, but they are beyond the scope of this *Teach-In*.

Some diode types (but not all) can be identified from the alphanumeric coding with which they are imprinted. In the European system for classifying semiconductor diodes, the coding can have either two letters and three figures, or three letters and two figures. The first two letters have the following significance:

First letter, semiconductor material:

A Germanium
B Silicon
C Gallium arsenide
D Photodiodes, etc.

Second letter, application:

A General purpose
B Tuning
E Tunnel
P Photovoltaic
Q Light emitting
T Controllable power rectifiers
X Varactors, multipliers
Y Power
Z Zener and reference

The third letter, where included, does not generally have any particular significance, other than to the manufacturer. Zener diodes, (explained in a future *Teach-In* part), have additional letters, which follow the identity numbers, showing the Zener voltage and its tolerance:

A = ±1%
B = ±2%
C = ±5%
D =±10%

However, it has now become less easy to identify diode types from their prefix letters and many codings exist which do not conform to the above standards, as will become apparent when studying manufacturer's diode data tables.

The American system for identifying semiconductor diodes involves a code which commences "1N". Diodes coded according to this system cannot have their function directly identified from their number, except by referring to data sheets and tables. It is thus recommended that when a diode's function or characteristics are unknown, its part number should always be looked up in a data table or a catalog.

Whilst most diodes have their identities printed on them as type numbers, sometimes identity numbers can also be color-coded onto the diode body, in the same way that resistors are color-coded. The colored bands are usually towards one end of the diode.

As we indicated towards the beginning of this part of *Teach-In*, holding the diode so that the bands are to the left, the code is read from left to right. For example, a diode marked yellow-brown-yellow-gray reads as 4148, i.e. it is a type 1N4148, one of the commonest general-purpose small signal silicon diodes.

POLARITY

The polarity of a diode is indicated in several different ways. With small diodes that have an imprinted alphanumeric coding (e.g. 1N4001), a painted band around the body indicates the cathode end. With color-coded diodes, the cathode is the end at which the color code begins. In some instances, it is the case style which indicates polarity (for which manufacturer's data should be consulted).

If in doubt, polarities can be checked using the diode-check facility found on many digital multimeters. They can also be checked using an analog meter, setting the meter on a low resistance range and connecting the probes across the diode. When in resistance (ohms) mode, a positive voltage is normally present on the meter's negative (common or "–") socket (black lead) and a negative voltage on its positive ("+") socket (red).

If a low resistance reading is indicated, the black probe is connected to the anode and the red probe to the cathode. A high resistance reading indicates that the polarity is the other way round.

The polarity of a LED is not always so easy to check using a meter. In most instances, though, the lead nearest the "flat" side of a LED is normally the cathode, the other lead being the anode. One way to check is to connect the LED in series with a 1kilohm resistor across (say) a 6V DC power supply. If the LED does not glow in one direction, try turning it around. If it fails to glow in this direction, it's probably dead (or you've forgotten to switch on the power!).

Others may be manufactured in such a way as to enhance the speed at which they respond, or to increase or decrease the capacitance which is inherent in any diode. Yet others may be more suited to video or audio signal processing for a variety of reasons, including low noise characteristics.

Data tables will usually give an indication of what sort of application a particular diode type is best suited to.

OTHER FUNCTIONS

The voltage blocking characteristic of a diode has other functions. For example, one function that can be performed by diodes, in conjunction with capacitors, is to increase the voltage of an AC waveform.

Diodes are also used to prevent damage to voltage sensitive components by preventing a potentially hazardous excess or opposing-polarity voltage from reaching them, and they have uses in signal compression and limiting.

When several diodes are used to feed voltages into or out of the same part of the circuit, they have the ability to be used as logical OR gates and AND gates (more on Gates and Logic is discussed in *Teach-In* Part 6).

As you discovered at the beginning of this *Tutorial*, in oscillating circuits they can also be used to change the relative rates at which a generated frequency rises and falls, converting a triangle waveform into a ramp waveform, for example.

OTHER DIODE TYPES

Apart from "ordinary" signal and rectifier diodes, there are several more types available, but of a more specialized nature, including:

o) Avalanche diodes
o) Bridge rectifier diode assemblies
o) Constant current diodes
o) Foldback diodes
o) Light emitting diodes (l.e.d.s)
o) Photodiodes (light sensitive)
o) P-I-N diodes
o) Schottky diodes
o) Tuning diodes (Varicap diodes)
o) Tunnel diodes
o) Ultrafast diodes
o) Varactor diodes
o) Zener or reference diodes

We suggest you read through Panels 4.2 and 4.6 for some more specific information about diodes in general.

LIGHT EMITTING DIODES

You have, of course, been using light emitting diodes (LEDs) since Part 1. It's time now to discuss them more fully.

Many materials can emit light when a current is passed through them. An ordinary filament bulb, such as used in a torch or a room light, emits light because its filament wire is heated.

Indeed, any electrically conductive substance will emit light if sufficient current passes through it so that it heats up above a certain temperature, even air (think of lightning in a thunderstorm); and there are some gases which can be made to fluoresce when a sufficiently high voltage is present across them, neon and argon, for example.

Some solids, though, have the strange property that they will emit light without being heated when only a small current at a low voltage level flows through them. Gallium arsenide (GaAs) is one such material, and it is from this that LEDs are typically made, usually in conjunction with other substances. Depending on the nature of the substances used, LEDs are available which can emit infrared, red, orange, yellow, green, blue and white light.

LED CONDUCTION

As with the simple diode discussed earlier, LEDs are used in the forward conducting direction, that is, the voltage on the anode must be higher than that at the cathode, typically between about 1·5V to 3V, according to the type.

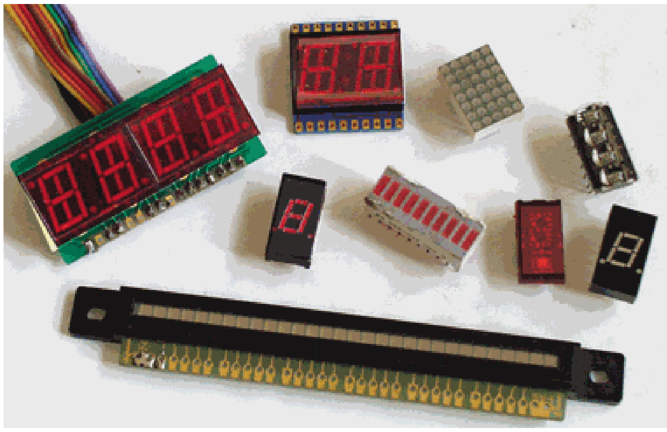


Photo 4.3. A selection of constructions that use multiple LED arrays.

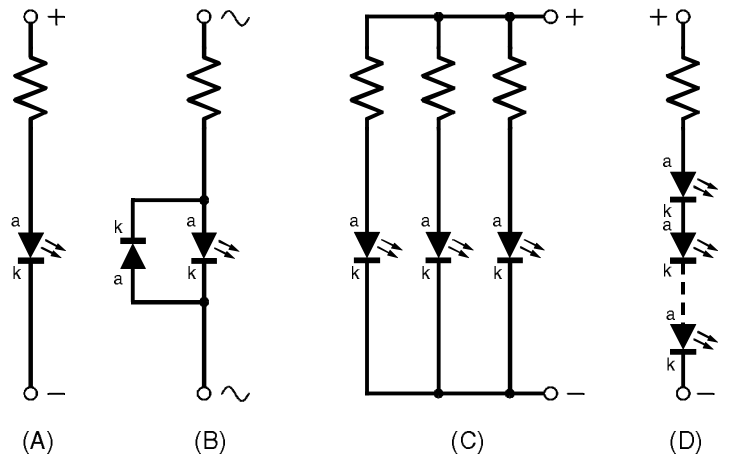


Fig.4.5 Methods of using (a) single LED (DC drive); (b) LED with diode in an AC circuit; (c) LEDs in parallel (DC); (d) LEDs in series (DC).

At much below the typical voltage level, the LED will not emit light. If the voltage is too much above that level, too much current will flow and the LED will die. Consequently, a resistor (known in this type of application as a *ballast resistor*) must always be used in series with a LED, either before the anode or after the cathode, its value being chosen so as to safely limit the maximum current flow, yet still allow sufficient for the LED to emit enough light as to be clearly visible, see Fig.4.5a.

Note, however, that some LEDs have a resistor built into their case and are intended for use with specific supply voltages, but this is an exception and most do not.

Depending on the type, LEDs begin to emit light when the current flowing is about 0·5mA to 1·5mA, but a current of between about 8mA and 20mA is usually required for good visibility to occur, although there are low-current LEDs that glow brightly with less current. The maximum current that a typical LED can tolerate is about 30mA (but data sheets should be consulted for specific types and their limits).

Compared to filament lamps, LEDs offer not only great savings in power consumption, but also offer advantages of a much longer life, smaller size, insensitivity to shocks and vibrations, and have a rapid response time.

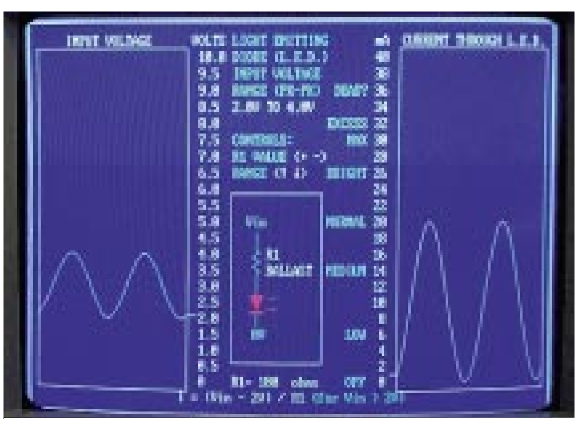


Photo 4.4. The interactive computer display illustrating how a LED responds to varying voltages and currents.

They can also be connected to an AC supply, although it is often desirable to have another LED or "normal" diode connected in parallel but with an opposite polarity, i.e. cathode to anode, anode to cathode.

In this instance, a single series resistor is used to limit the current through one or other common connection, see Fig.4.5b. This action keeps the voltage level across each diode within acceptable limits during its reverse voltage condition.

With a DC supply voltage, it is sometimes required for several LEDs to be connected in parallel, all having the same polarity and each turning on at the same time. In this case it is preferable to use a separate series resistor for each of them, see Fig.4.5c.

The reason is that each LED is likely to have slightly different current requirements and the use of a single resistor would favor the most current-hungry one, to the detriment of the light output from the others. Additionally, this method is also preferable in case one LED should die, forcing an unacceptable amount of current through the others, threatening their life as well.

Any number of LEDs can be connected in series as long as

Photo 4.5. A selection of diode and bridge rectifier types.

the supply voltage available is high enough to overcome their total forward voltage drop. A single resistor is used to limit the current in the normal way, see Fig.4.5d.

Of historical interest, LEDs were patented by Messers Bay and Szigeti in 1939.

Panel 4.3 details some of the characteristics for LEDs.

PANEL 4.3 - L.E.D CHARACTERISTICS

The principal characteristics of LEDs are:

o) IF – typical forward current
o) IF(max) – maximum forward current
o) VF – forward voltage
o) VR – reverse voltage
o) PTOT – power dissipation
o) A – area of light collecting surface; may also refer to the maximum angle at which the light emission can be reasonably viewed
o) Wavelength of the maximum emitted light intensity, in nanometers (nm)
o) Light intensity for a given current

LEDs are available not only as individual items, but also as multiple units, arranged so that each one within the unit can be individually controlled. Such multiple units include 7-segment displays and general-purpose matrixed devices, in which there are several rows of diodes and several diodes in each row (see Photo 4.3).

When matrixed, the LEDs will either have their cathodes joined (common cathode type) or their anodes (common anode type). The two types are not interchangeable in a circuit.

Some units have two LEDs in them, electrically facing in opposite directions and having different colors. The color displayed depends on the current flow direction.

There are even some devices which house four LEDs in the same package producing a mix of output colors, including red, orange, yellow, green, blue or white. Another LED type has an additional circuit built in which causes the light to flash when power is applied.

In circuit diagrams, the numerical identity of an individual LED is usually prefixed by the letter “D”, although it may also be prefixed by “LED” or “LD”, or sometimes by “LP” (short for Lamp). Units which contain several LEDs may be prefixed by the general catch-all prefix “X”, e.g. “X2”.

In catalogs, LEDs may be listed under “Optoelectronics” rather than under “Semiconductors”.

LED PROGRAM

From the program’s main menu, select *Light Emitting Diode*. The screen will again display two waveforms (see Photo 4.4). The one on the left represents a positively biased sinusoidal voltage being input to a LED via a resistor (the ballast resistor.)

It should be noted that a LED is usually powered from a steady DC source. The screen shows a sinusoidal waveform because it better illustrates the way in which the LED responds to different voltages and currents.

The graph on the right illustrates the current that passes through the LED and ballast resistor. Alongside this graph are captions that indicate the type of response that a typical LED might produce for a given current.

The LED in this example is assumed to have a forward voltage drop of 2V. The current that passes through it is calculated as:

I = (Vin – 2V) / R1

This formula only holds true if the voltage across the LED is greater than 2V. For a voltage less than this, no current will flow.

The range of the input voltage can be raised or lowered using the keyboard up and down arrows. The value for R1 can be changed using the <+> and <–> keys.

As said previously, different LED types may have different current characteristics etc., and the program should only be taken as an approximate guide to how a LED will respond.

ZENER DIODES

Zener diodes, which are used to regulate (fix) voltages at particular reference levels, will be discussed later in the series when we look at power supplies. However, for interest, you can learn a bit about Zeners now by running the software menu option Zener Diodes.

BRIDGE RECTIFIERS

A frequently encountered type of diode construction is the bridge rectifier (see Photo 4.5). In fact, this is not a single diode, as are the others in the list

PANEL 4.4 – UNUSED LOGIC GATE INPURTS

Note that in Fig.4.1 the inputs to the unused inverters in IC1 have been connected to either +VE or 0V. (See Fig.2.10 of Part 2 for the 74HC04/74HC14 hex inverter pinout diagram.) We did not wish to trouble you with this point before, but it is good practice to always connect unused CMOS logic gate inputs to one or other of the power supply lines.

This prevents them from "floating" and picking up stray electrical interference and static electricity. It is only unused *inputs* which need to be "tied" in this way. **Never tie unused *outputs* to the power rails.**

given earlier, but a group of four silicon diodes connected as shown in Fig.4.4.

However, because bridge rectifiers are normally used in power supply circuits, they will be discussed when we examine that subject.

SPECIALIST DIODES

In Panel 4.5 are brief details of some specialist diodes which will not normally be encountered in most hobbyist applications. This information is primarily given so that you know that such devices exist.

ON DISPLAY

We suggest that you now move on to the *Experimental* article. It's different in concept to those you enjoyed in Parts 1 to 3. This time we ask you to assemble the first part of a simple circuit that allows your computer to input waveforms and voltage levels from the circuits you have been creating so far, and those yet to come. It's an eye-opener!

Then, in Part 5 next month, we examine different waveform shapes, and shall be able to illustrate some via the computer display – not only as simulations but as actual real-time waveforms that you create via your breadboard.

PANEL 4.5 – MISCELLANEOUS DIODES

Avalanche diodes

Avalanche diodes have similar voltage and current characteristics to "ordinary" Zener diodes, but have a much greater surge handling capacity combined with extremely fast switch-on times. They are commonly found in voltage suppression applications.

Constant current diodes

Because of their superior stability, constant current diodes are ideally suited for use as current regulators and limiters, biasing elements, and for use in linear ramp generators, staircase generators etc.

Foldback diodes

A foldback diode is a device that, under voltage surge conditions, enters the avalanche mode as normal, but causes the voltage to fall from that of a breakdown value to a clamping value, which remains substantially constant over a wide range of current. They are mainly found in voltage suppression applications.

P-I-N diodes

A P-I-N diode is a refined version of the "basic" p-n junction diode with special characteristics that make it suitable for use at radio frequencies. The letter I indicates that the diode has an "Intrinsic" layer sandwiched between the p and the n layers – a technicality outside the scope of this Tutorial.

Schottky diodes

A Schottky diode is a sophisticated type of diode which has a forward voltage drop that is typically about half that of a "normal" silicon diode, and has a fast reverse recovery. It finds particular use in switch mode power supplies where such attributes offer greater power conversion efficiency.

Tuning (Varicap) diodes

Tuning diodes are designed to vary their capacitance in response to changes in the voltage across them, and are thus equivalently known as Varicap (variable capacitance) diodes. They are especially used in high frequency tuning applications, very high frequency (VHF) and ultra high frequency (UHF) radio tuning for example, in place of the rotary type of variable capacitor whose capacitance range is too coarse or too large to be practical. Their use also has the great benefit that no mechanical action is involved.

Tunnel diodes

Tunnel diodes are specially processed diodes whose forward conduction displays a negative resistance characteristic. Such diodes can be used in low noise amplifiers or in oscillator circuits, up to microwave frequencies.

Ultrafast diodes

Ultrafast recovery rectifier

diodes feature high reverse voltage capability, very short recovery times, very low switching losses, and low-noise turn-off switching. They are suitable for use in switch-mode power supplies and similar fast rectifier applications.

Varactor diodes

Varactor diodes are another type of diode whose capacitance can be changed according to the applied voltage. They find use in voltage multiplying circuits (doubling, tripling, etc.), where their non-linear action can be used to generate harmonic multiples of a fundamental frequency.

TEACH-IN 2000 – EXPERIMENTAL 4

COMPUTER INTERFACE

What we want to do in this *Experimental* article is to enable you to use your computer as an item of test equipment. This will let you make very simple connections between the computer via its parallel printer port cable and your various breadboard circuits – past, present and future.

In other words, we are going let the computer become a simple form of oscilloscope – an item of test equipment that shows both digital and analog waveforms on its screen while they happen.

Don't expect the full facilities or speed of a true oscilloscope, or indeed of commercial computer-based oscilloscope simulators. Such items would set you back several hundred UK pounds. By comparison, our simple interface should cost you less than 20 UK Pounds.

It has to said, though, that the speed at which your computer runs will have a significant bearing on the rate at which the program can obtain data from the interface. This will place limits on the signal waveform frequency that can be displayed.

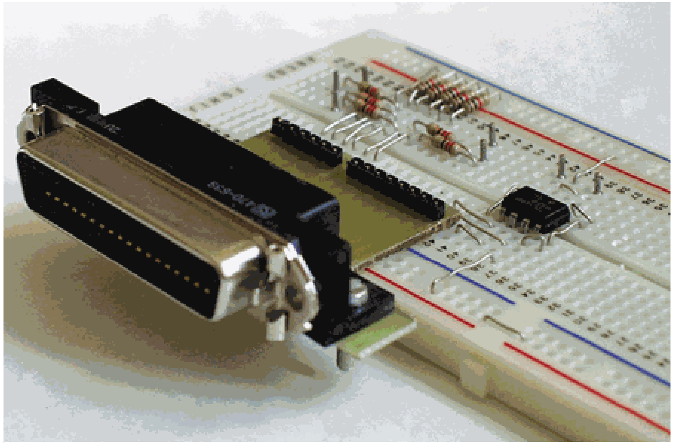


Photo 4.6. Computer interface connector plugged into the breadboard.

INTERFACE MODULE

Basically all the interface consists of is a connector socket into which a standard (Centronics) parallel printer port cable plugs. The socket's pins are on a different spacing to that of your breadboard and so we have produced a specially designed printed circuit board (PCB) into which you need to solder the connector and a set of terminal pins. The terminal pins then plug into your breadboard.

This set-up allows the computer to read the status (logic 0 or logic 1) of five separate connections made to its input lines. Additionally, eight other separate connections can be made to the computer's output lines, allowing it to control various future breadboard assemblies.

Next month we also describe and illustrate a very simple breadboard circuit, using just one IC, that will allow you to actually see on screen the waveforms that you create with the oscillator described in this month's *Tutorial*.

IT'S AN EYE-OPENER

You will find that using this simulated test gear facility, with its four program options, is an absolute eye-opener. When the author first used an oscilloscope in his early days of electronics (long before computers were even imagined to be commonplace household items) it was like having a blindfold removed from his eyes. He could actually see what was happening. (Moreover, he actually built the oscilloscope himself from ex-Government "surplus" components.)

Whilst you will have found out that reading a meter display

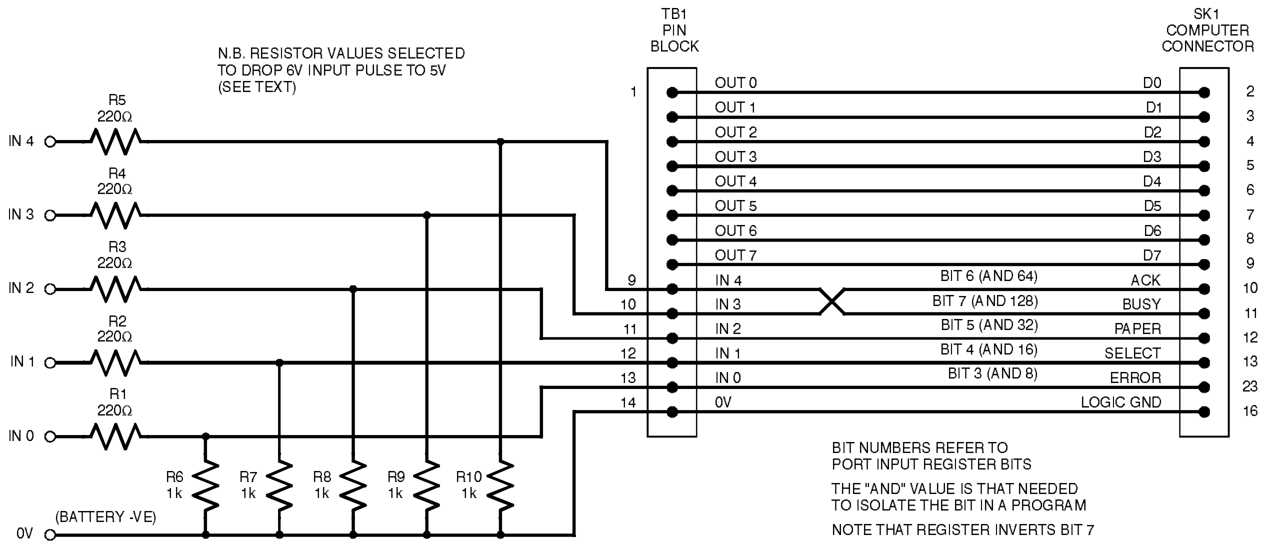


Fig.4.6. Circuit diagram for the simple breadboard to computer interface.

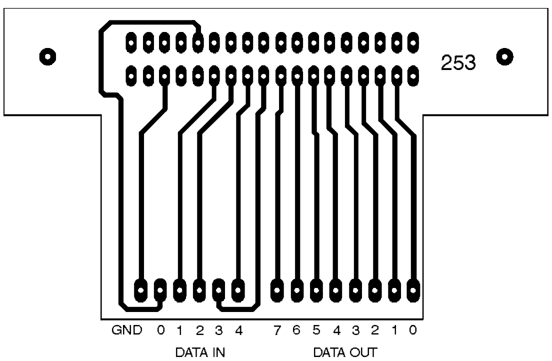


Fig.4.7. (Approximately) full size printed circuit board copper foil track master layout pattern.

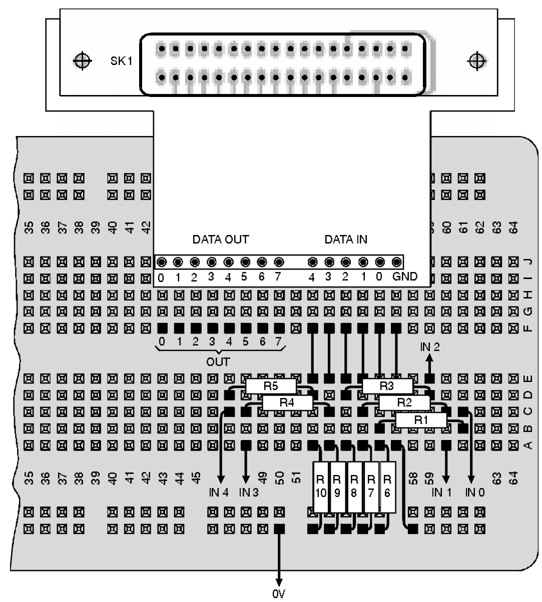


Fig.4.8. Component layout for the computer interface circuit.

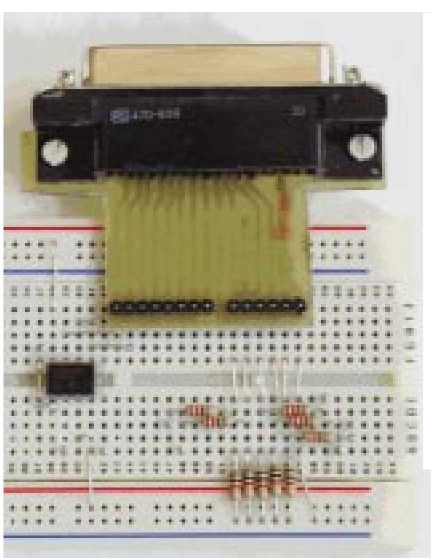


Photo 4.7. Computer interface component layout details. The integrated circuit on the left (and its additional connections shown) are the analog to digital converter interface to be described in part 5.

has been very informative to you so far (and will continue to be so), this computer interface will open up your electronics horizons even further.

Having said that, though, when you become more experienced in electronics than you are now, do purchase a real oscilloscope (or even a virtual 'scope – one that uses an interface unit plus a PC as the display controller). It will allow you to do far, far more than our simple interface can do, and at an enormously faster rate. In the author's workshop a 'scope is without doubt the most used item of test gear he has, the second is/are his multimeters, and thirdly is/are his computers.

INTERFACE CIRCUIT

The complete circuit for the basic digital interface between the computer and breadboard is shown in Fig.4.6. A second part to the interface will be described next month – the part which allows analog waveforms to be input, the analog-to-digital converter (ADC).

The computer's parallel printer port has eight output data lines, D0 to D7, which are connected to a terminal pin block, at which point they become re-named as OUT0 to OUT7. There are also five printer port lines, which can be used as data inputs from terminal pins IN0 to IN4. Strictly speaking, they are normally used by the printer to send status messages back to the computer, hence their names at the computer end.

The resistor configurations are included in the IN0 to IN4 data lines to keep the voltages input to the computer below 5V. It is assumed that your computer's voltage input limit is 5V. Your breadboard circuits, however, are powered at about 6V. What the resistors do is to reduce (attenuate) the 6V levels to 5V.

PRELIMINARY ADVICE

To assemble your interface connector board, it is necessary to do just a bit of soldering. In the Introduction to Part 1 we said that some would be needed and recommended that, if you were unfamiliar with soldering, you should peruse a copy of our *Basic Soldering Guide* from the *EPE Online Library* at **www.epemag.com**

As you will see from the interface board's assembly and

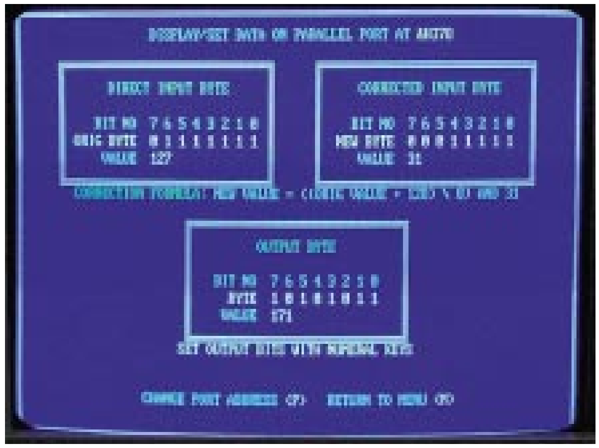


Photo 4.8. Parallel Port Display/Set screen on the interactive computer display.

tracking details in Fig.4.7 and Fig.4.8, you should not find these few solder joints hard to make. Having made them, though, it is imperative that you should check that none of the joints undesirably link with others.

With a close-up magnifying glass, double-triple check that there are no solder connections between adjacent pads or tracks. If there are, just touch the hot soldering iron to them and they should separate. If this fails, use a sharp knife or scraper tool to cut through the offending connections.

As an additional check, use your multimeter on a low Ohms range to check that adjacent tracks/joints on the board are isolated from each other.

The *Teach-In* Computer Interface printed circuit board is available from the *EPE Online Store* (code 7000253) at **www.epemag.com**

INTERFACE ASSEMBLY

Carefully push the computer connector socket pins through the holes on the printed circuit board, so that they protrude on the "track side". Do not solder them yet. Securely bolt the socket to the board through the two holes provided, enlarging them with a drill if necessary. Now carefully solder the pins to their tracks. Ignore those pins hat do not have tracks – they do not need to be soldered.

Take a strip of terminal pins and cut off a length of eight and a length of six. Turn each strip so that its shorter pin lengths are downwards, and press the strip firmly onto a hard surface that will not damage and cause fury in your household! Press down until the pins are barely protruding on that side (but just enough showing so that a meter probe can contact each one).

Insert the terminal strips into the board, with their pins protruding from the trackside, and solder them. Now check that all the solder joints are OK, as cautioned above.

When satisfied with the board, press the assembly firmly into the end of the breadboard as shown in Fig.4.8 (also see Photo 4.7). Note the breadboard hole numbers and position the assembly accordingly. Do not insert into the breadboard the other components shown until we tell you to.

INTERFACE TESTING

With one end of the computer's parallel port printer lead plugged into the computer (and with the computer switched off), plug the other end into the interface board assembly. If any other equipment is connected to your printer port via an adapter, disconnect it.

Power up the computer in the usual way. In the unlikely event that the computer behaves in any way out of the ordinary, immediately switch it off, unplug the connector from the interface board and recheck that all the solder connections are satisfactory.

From the *Teach-In* main menu select *Parallel Port Data Display/Set*. On the resulting screen are three boxes of data, as shown in Photo 4.8.

The two upper boxes are associated with data input. The lower one, *Output Byte*, is concerned with data output and is the one we are interested in first.

As we shall explain further in Part 6, a computer byte of data consists of eight bits (of data), where each data bit can be set high or low (logic 1 or logic 0). The bits in this instance are those that can be set onto the eight output lines on the interface board, 0 to 7 (many identity numbers in computing and digital electronics commence at 0).

In the *Output Byte* box, the first line shows the bit numbers in reverse order (another computer/digital convention). Each of the bits can be set high or low from your keyboard, using the same numbered keys. Line two (Byte) shows the status of each bit as you set or clear it (1 and 0 respectively).

The arrangement of the bit values of the byte is in fact a binary number (although in many applications this fact may not be important) and its value in decimal is shown in line three, *Value*.

Experiment with pressing your numeral keys and see the effect in the Output Byte box. Now, with your multimeter on a suitable scale for reading 5V DC, take voltage readings at the top of the OUT0-OUT7 terminal pins. The meter's COM probe should contact with the GND terminal pin. For each logic 1 shown on screen, that same OUT terminal pin should read about +5V. For logic 0 it should read as 0V.

It is regrettable that the order of the connector pins dictates that the numerical order of the terminal pins has to be the reverse of that on screen; be aware of this when taking the voltage readings.

PORT ADDRESS

You may have now found a small problem – it doesn't work! A three-in-one chance, perhaps, that this is so. The problem you may encounter is that the computer has internal settings that dictate by which "register address" (route) data is output to its parallel printer port pins.

The address frequently used is that at port register location &H378 (378 hexadecimal – 888 decimal) and this is the address used as the default by the computer program. It is stated as such at the top right of your screen. There are two other addresses that might be encountered on your computer system, &H278 and &H3BC (decimal 632 and 956). Your program can be set to use either of these instead. (Incidentally, hexadecimal and binary numbers are discussed in Part 6.)

Press <P>, to change the port address to &H278. Now try the above tests again. If the pins still do not change their logic state in response to your numerical keying, press <P> again to select port address &H3BC. Try the pin logic test again.

If none of the port addresses allow you to set logic values on the terminal pins, again recheck all your assembly, including proper connection of the printer port cable at both ends. If there is still no success, consult your computer manual or supplier. (Please also tell us at *EPE Online* about this, stating the computer type and what voltage readings you actually get.)

Once the correct port address has been found, it will automatically be stored for future use by the program when you next call the main menu. Note that it is our software that holds the address – no change is made to the computer's own system data.

DATA INPUT TEST

Having completed the data output test, it seems logical to do an input test! Plug resistors R1 to R10 into the breadboard as shown in Fig.4.8 and with values as shown in Fig.4.6. (Do it with the computer unplugged from the breadboard.)

With the computer reconnected, look at the two top boxes on the computer screen and make a note of the binary and decimal values shown. We shall discuss the difference between the two boxes next month. The right-hand box (box 2) should show binary bits 4 to 0 as zeroes.

Clip your battery's negative lead to the 0V pin on the breadboard. Now clip the battery's positive lead to the IN0 pin on the breadboard. In box 2, bit 0 should have changed from logic 0 to logic 1. Removing the positive lead from the IN0 pin should return that bit to logic 0.

Do the same for the other breadboard input pins, IN1 to

IN4. All should change status accordingly.

The success of this test depends on the Port address still being set to that found necessary for the Output test.

PULSE TEST

Remove the battery connections used for the Input test. Connect the battery back onto the power input pins for the oscillator circuit you were using in this month's *Tutorial*.

Ensure that a link exists between the 0V connection of that circuit and the 0V connection of the interface circuit. Make a crocodile-clipped connection between IC1a pin 2 (Fout) and interface input IN0.

Set VR1 of the oscillator to a midway position and use a 100uF (or greater) capacitor for C1. This allows a square wave at a slow rate to be sent to the IN0 pin.

Observe bit 0 of screen box 2. It should repeatedly change between 0 and 1 in time with the changing output of IC1a. You can try adjusting VR1 to change the rate, but you will find that at the more extreme settings the computer may fail to respond. This is because one or other side of the waveform is too brief for it to be recognized by the computer. This will be especially true with slower computers.

What you can do to alleviate some of this problem is to remove both diodes (D2 and D3) from the breadboard, and place a 1kilohm resistor in the D3 position (as you did at the beginning of the this month's *Tutorial*). This will cause a square wave output to be generated whatever the setting of VR1. The oscillation rate, though, must be kept slow enough for the computer to respond to it.

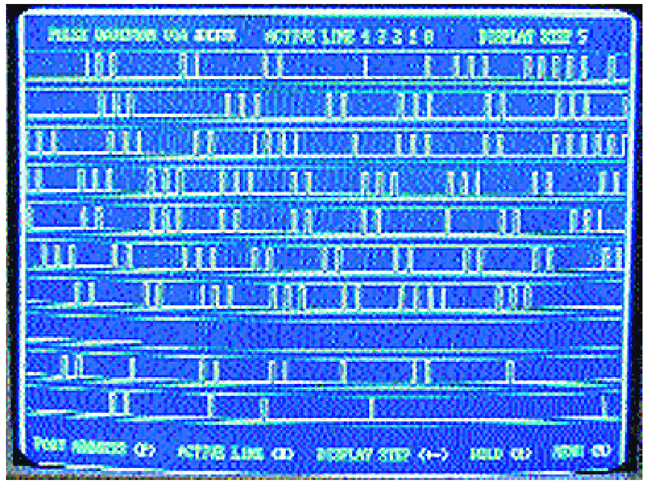


Photo 4.9. Typical pulse waveforms input to the computer via the simple interface board.

Just for interest, observe box 2 when the oscillator is connected to any of the other interface input pins.

UNTIL NEXT MONTH

Next month we shall discuss other aspects of the computer interface and its program. Until then, though, you can experiment with the *Frequency Counter* and *Pulse Waveform* displays, both of which are selectable from the main menu.

In both programs you have the option to set the "active bit", in other words to specify to which of the interface input pins the oscillator is connected. In the case of the *Pulse display*, also experiment with the *Display Step* option.

Do not change the Port address that you found to be active in the original Output tests.

If your computer has sufficient speed, try speeding up the breadboard oscillator's rate.

We shall explain both of these programs next month, and describe the additional (and very simple) breadboard circuit that will let you display the shape of the waveform that occurs at the VR1/C1 junction of the oscillator, via the *Analog Input Waveform Display* program.

We shall also discuss waveform shapes in general.

Until next month, then, 'bye!

Go to next section

Net Work

SURFING THE INTERNET

By Alan Winstanley

SWEET DREAMCASTS

Before Christmas I treated myself to a Sega Dreamcast games console to replace my redundant Mega Drive (Genesis in the USA) for entertainment purposes. This terrific fan-cooled 128-bit games console has an internal 33·6 modem and BT phone lead. Sega provides their own limited Java, Flash and MPEG-aware web browser disk (the Sega Dreamkey), so naturally it wasn't long before the inevitable happened and I attempted surfing the net using the TV as a monitor and the Dreamcast software keyboard to type an E-mail.

Sega's UK Internet service is managed by BT, and ultimately players will be able to challenge adversaries from all over Europe (but not, it seems, anywhere else in the world). The first stage is to create a user ID via the Dream Arena web site, which gives you a free **dreamcast.com** E-mail address. The access speed was then adequate enough to visit a web site or two, although many page layouts were altered drastically by the fact that they are viewed at a fixed width using a TV browser.

Considering that many web developers agonize at their clients' expense over the most trivial of design details, they all overlook one market yet to emerge in the UK – Web TV. Experience of using Sega's web browser on a TV set provides a taste of things to come for many home Internet users, when more Web TV users will gradually start to gain access to web sites (especially if they don't have a PC).

If web sites wish to capitalize on the emerging medium of Web TV, they will need to offer a Web TV option which has a fixed width page, large legible fonts that can be viewed from ten feet away, and few navigation choices. HSBC Bank already offers on-line banking by digital TV and there are many more services to come.

The Dreamcast software keyboard uses the gamepad to "press" the on-screen keys and is a pain to use, so Sega's separate AT-style keyboard (price 20 UK Pounds) would be essential for more enthusiastic use. At the moment it would barely be worth the cost except for sending the very briefest of E-mail messages. This is because the Dreamcast provides an on-line E-mail client, so legions of Sonic the Hedgehog lovers (or their parents) are faced with making standard local-rate BT calls to compose and fetch E-mail whilst logged in to the Dreamcast web site. It would make an entertaining introduction to E-mail and the web, though.

CUT THE PHONE TARIFFS

A friend from the USA recently visited for a few days so we decided to compare phone prices. Life for an Internet user in the Dallas Metroplex is a whole lot rosier than that of a British Telecom customer. My Texan pal uses an ordinary 56K modem and for a flat rate of \$19.99 (12 UK Pounds) a month he enjoys unlimited 24 x 7 Internet access. In fact he gets it for \$12 (7 UK Pounds) because of loyalty discount options. Local phone calls are free, as are Internet access calls. Using a Net-Zero account (**www.netzero.net**), for the price of a banner advert on his desktop, he enjoys a free ISP.

The cost of Internet access in the US has become almost forgettable. It is not surprising that the US press boasts of how America is beating the English – supposedly the nation of shopkeepers – at their own game. American E-commerce seems to be thriving (which is why I just ordered the SETI@home T-shirt from the US today), whilst UK Internet commerce is being strangled at birth in what has rapidly become a national scandal of prohibitive phone call costs.

Remember that most users are fleeced by the BT minimum charge of 5p (8 cents) for each and every call. This aspect is almost as punitive as the lack of "unmetered" (flat rate) phone calls. I can dial in and collect the latest batch of E-mail text messages from all my POP3 boxes in under a minute (equivalent to about 1p at off-peak prices) during the day, but in effect I will pay five times that value because of the minimum charge. Every Internet access call, whether through a Sega Dreamcast or your PC, costs 5p minimum and some Internet Content Providers (notably AOL) now actively dwell on con-

sumers' fears of racking up large phone bills. AOL wants 9.99 UK Pounds a month and the call is still a penny a minute.

CHRISTMAS LITMUS

Over Christmas '99, many radio and TV consumer programs chattered excitedly about the new-found novelty of purchasing goods over the Internet. Americans will laugh, but for many UK consumers, last Christmas will have been a litmus paper test for E-commerce. Now that the Internet is trendy and appealing (and not to mention a whole lot more usable), consumers are taking to ordering on-line like wildfire, and they are proving adept at sniffing out the best deals. By next Christmas the novelty of E-commerce will be taken for granted, and users will simply be concerned with finding the cheapest bargains from the most likely-looking suppliers.

Unlike the service enjoyed within the Dallas Metroplex by my acquaintance, thanks to BT's pricing and their ownership of the local loop, the situation in the United Kingdom could almost have been engineered to inhibit the uptake of the Internet by the mass market. Even looking at their high-level services, BT has subsequently backtracked on the bandwidth availability on ADSL – the available speeds have been reduced, and the cost price has been increased at the same time.

BT recently proposed the launch of BT Surftime, billed as an "unlimited access price package". Naturally, nothing is simple and the end user is offered a number of pricing options, none of which permits local voice phone calls. It is only after many months of use, if not years, that users can build up an accurate picture of their likely Internet requirements. Newcomers to the Internet must therefore take a shot in the dark regarding the best choice of tariff for them. BT's new scheme is based on its interpretation of the nation's browsing habits and for many it will be as bewildering as selecting a mobile phone tariff.

The proposals are these: **Weekend Internet** would cost 6.99 UK Pounds per month inc. VAT for unlimited weekend access. Or you could try the **Evening and night-time Internet** option instead for the same price, which provides unlimited access in the evening and night-time from Monday to Friday. Alternatively there's always the proposed **Daytime Internet** option which jumps to 26.99 UK Pounds per month for unlimited access Monday to Friday, or 1p a minute at all other times.

For heavier users like myself, there's the so-called **Anytime Internet** option at 34.99 UK Pounds per month ($58) charge for unlimited access at any time of any day. (At this point, my Texan friend started to laugh.) BT's 24 x 7 Internet option is thus nearly five times the cost payable in Texas after loyalty discount, and it still excludes local voice calls. Indeed, for only $40 a month Texans can enjoy cable modem access, offering a 100 to 120-fold increase in bandwidth over a V.90 modem. Cable modems are starting to roll out in the UK too, with ntl [sic] gearing up to offer a range of hosting services as well.

I almost omitted BT's **"pay-as-you-go"** option priced at 1p per minute evening, night-time and weekend or, naturally, double that price during the day. It is not yet clear whether the minimum 5p call has been ditched, but at the time of writing OFTEL has yet to approve the new package anyway, which will be "subject to availability".

The Campaign for Unmetered Telecommunications (or CUT for short) has an extensive web resource devoted to the campaign for unmetered phone calls, at **www.unmetered.org.uk**. I fear they still have a lot of work to do, and I wish them luck.

Go to next section

LIVE WEB EVENTS

Barry Fox reports on the latest attempts to improve live action on the Web.

Philips wants to extend E-commerce on the Internet to pay-viewing of special events, by exploiting a feature of the newly ratified MPEG-4 standard. MPEG-4 can carry acceptable pictures and sound at a few tens of Kbps, because it is object-oriented. The stationary background and moving foreground are separately coded, and re-combined in the PC. Background ambient sound is separately coded from speech or music.

Philips has developed a system that uses MPEG-4 to provide an overall view of a sports pitch or concert stage, along with background crowd noise. The players and performers only appear on screen, and the music or commentary are only heard, when the PC-user pays a fee by credit card. Advertisements on boards are tailored to the location of the target audience.

Web Overload

However, as proved by the Netaid live Webcast, the Internet has a long way to go before it can challenge conventional TV, and paying for faster PCs and ISDN access into the home is no answer if the main delivery system is overloaded. This message came over loud and clear from the fuzzy disjointed video images that arrived from Web cover of the Netaid pop concerts held in London, Geneva and New York on 9 October '99. The UN-backed website (**www.netaid.org**) used 1500 servers at 90 locations round the world.

Cisco Systems (**www.cisco.com**) and the organizers designed the system to handle 125,000 simultaneous hits, and one million a minute – ten times the peak rate for Internet cover of the last Olympics. Netaid's target was to break the billion hit barrier.

Internet news reports after the event (**http://dailynews.yahoo.com**) put the total number of people who visited the site at 2·4 million. Those who did log on had to download the latest version of the RealPlayer G2 decoding software before they could receive live video and sound (**www.realaudio.com**).

Even with 64Kbps ISDN access to the Netaid site, with a Pentium 3 processor running at 500MHz and Windows 98, the postage stamp live pictures frequently collapsed into an irregular display of frozen and blurred images. Material coded at 34Kbps often delivered at an average of 4Kbps, sometimes dropping to zero data rate. Motion was, at best, very jerky. Sound quality remained-reasonably consistent throughout.

Those who watched on TV got a much better deal. The BBC in Britain promoted the event through its own Web Site (**http://news.bbc.co.uk**) and joined with MTV to broadcast the concert live. TV stations in 60 countries relayed the event. UNESCO also offered a menu of audio interviews on its Web Site (**www.unesco.org**).

Flash Trap Folly

By Barry Fox

After a year's development work, a British invention that can fool vehicle speed trap cameras recently went on sale for 200 UK Pounds. The Home Office says it is "unreliable and ineffective" and anyone who tries it risks arrest for "conspiring to pervert the course of justice" and contravening the Department of Transport's Construction and Use Regulations.

Photographer Alwyn Morris licensed Backflash of Mansfield in Nottingham-shire to manufacture and market the device which he patented a year ago. A slave flash unit by a car's number plate is triggered by any photo flash and reacts so quickly that it fogs the film or blinds a digital image sensor. The slave reacts either to visible flash or infrared as used in some new cameras to trap motorists without their knowledge.

Although Backflash explains how the slave can be fitted near a car's number plates, and proved to work by taking a Polaroid photo or pointing an infra-

red TV control at it, the company adds the disclaimer “we do not advocate use against traffic enforcement cameras”. The recommended use is to protect famous people against paparazzi cameras. The Department of Transport and Highways Agency reckons that no company could get rich on selling only to camera-shy celebrities. “Apart from breaking the law” says a Home Office spokeswoman “the police can still read a fogged image by reversing its positive/negative polarity”. When Backflash failed to answer questions, spokeswoman Jane Cheffings explained that “Those responsible for the invention felt it inappropriate to continue the conversation ... you will see from the media coverage and technical data this is the information we are willing to enpart (sic)”.

FREE PIC BASIC

FOR those of you who don’t feel inclined to learn PIC Language (but you could, easily, if you wanted to), there is a *Free* PIC Basic Compiler for Win95/98 available for download from Leading Edge Technology’s website. LET has released this program to encourage the use of the Microchip PIC16Cxx series of microcontrollers, along with the company’s range of low-cost PIC programmers and related products. The compiler supports PIC types ’54 to ’57, ’71, ’84 and ’508/9.

For more information contact Leading Edge Technology Ltd., Dept EPE, White Rose House, Triq Ix-Xintill, Tarxien, Malta PLA11.

Tel: (00356) 678509

Fax: (00356) 667484.

E-mail: johnmorr@email.keyworld.net

Web: http://let.cambs.net

Big Cheese Declares War

AS part of the next BBC2 *Robot Wars* series, a radio-controlled robot tastefully (?) called *The Big Cheese*, will be taking part. It is shaped like a large wedge of cheese and is sponsored by dairy company St Ivel. Roger Plant of Plant Engineering in Somerset is the designer.

Of technical interest (rather than gastronomic) is the fact that the robot is controlled by low power radio modules from Wood & Douglas. The ST500 and SR500 synthesized transmitter and receiver used cover the 400-500MHz band and have multichannel capability. The sensitive receiver and matching 100mW transmitter are ideal for short and medium range applications.

Comments Roger Plant, “Having competed in *Robot Wars* before, we believe we’ve got it right this time”. His previous robot, *The Mule*, was voted the best engineered robot in the last series of *Robot Wars*.

Wood & Douglas Ltd can be contacted at Dept EPE, Lattice House, Baughurst Road, Baughurst, Tadley, Hants RG26 5LP, UK.

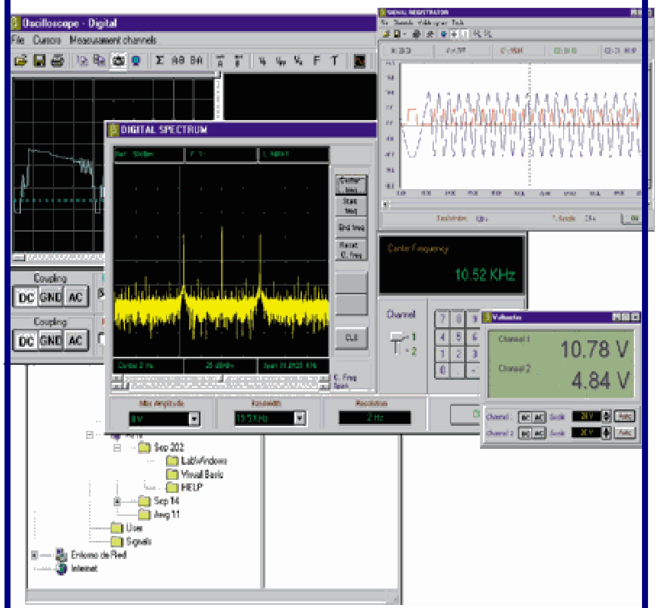
Tel: +44 (0) 118-981-1444

Fax: +44 (0) 118-981-1567

E-mail: info@woodanddouglas.co.uk

Web: www.woodanddouglas.co.uk

LOW COST VIRTUAL TOOLS



Two low cost single and dual channel PC-based test instruments have been released by test and measurement specialists Vann Draper Electronics. Both models feature a 20MHz real-time, 40Ms/s digital storage oscilloscope, 20MHz spectrum analyzer, one second to 999 hours data logger and an AC/DC voltmeter.

The virtual instruments are designed to look and operate like conventional bench instruments. They include cursor and on-screen readouts of amplitude, frequency, trigger level and time. Results and waveforms can be stored either for future reference or additional analysis. A simple plug-in card operates with a PC under Windows 3.1, 95, 98 or NT.

The SCP201 and SCP202 are priced at 159 and 199 UK Pounds, respectively, and are equally suited to applications in industry, education, production and service. The software allows the addition of other instruments in the range to be easily added. Full demonstration software is available on CD-ROM.

For more information contact Vann Draper Electronics Ltd., Dept EPE, Stenson House, Stenson, Derby DE73 1HL, UK.

Tel: +44 (0) 1283-704706

FREE ETPSOFT

Astonishing – the popular *Electronics Principles* educational software has been made available to hobbyists, students and engineers *absolutely free*!

We have never had occasion to doubt the sanity of our friends at eptsoft Ltd (who used to trade as EPT Educational Software) and we can't believe it's slipped now, but *free* software? . . . Well, they must have a good reason, as well as still having the Seasonal Spirit of Christmas (and the Millennium)!

Electronics Principles on-line electronic course is a huge "virtual textbook" of electronics information, containing hundreds of worked examples, from simple DC theory to PIC microcontrollers, over a thousand colorful electronics images and accompanying text.

It has been explained to us that the company's fully interactive software package, *Electronics, Electrical and Mathematics Principles V6*, is available in hundreds of UK colleges, including many of the top universities, as supporting software for electronics courses. Providing *Electronics Principles Online* free gives students the opportunity to access this information as a follow-up to their studies outside the classroom.

As an additional service to students and those wishing to study electronics, eptsoft Ltd is inviting colleges and universities to provide website addresses to enable quick and easy searches to be made when investigating UK electronics courses.

For more details contact eptsoft Ltd, Dept EPE, Pump House, Lockram Lane, Witham, Essex CM8 2BJ, UK.

Tel/Fax: +44 (0) 1376-514008

E-mail: info@eptsoft.com

Web: www.eptsoft.com

Electromail's CD-ROM Cat

Recently received at the UK HQ is the latest Electromail CD-ROM catalog. As sister company to RS Components, which is one of the UK's largest distributor of electronic, electrical and mechanical products, Electromail makes this vast range available to technical hobbyists and small businesses. The CD-ROM catalog contains over 107,000 products, as well as an extensive library

of datasheets, and access to specialized technical helplines.

The CD-ROM costs 3.99 UK Pounds and is available by post, or by phoning or faxing with credit card details. Contact details are:

Electromail, PO Box 33, Dept EPE, Corby, Northants NN17 9EL, UK.

Tel: +44 (0) 1536-204555

Fax: +44 (0) 1536-405555.

The RS website is at **http://rswww.com**

Jackson Tuning Caps Revived

It will be a relief to readers involved in radio receiver design to learn that, after experiencing severe financial problems, the renowned Jackson Brothers company has been purchased by Mainline Electronics, and that the future production of variable capacitors and ball drives is assured. The first catalog produced under the new ownership has been received at our UK HQ. It is well worth acquiring. New ranges of products are planned.

A longer report appears in the Christmas '99 issue (No. 62) of our sister publication *Radio Bygones* (**www.radiobygones.com**). The full story of Jackson's earlier troubles makes harrowing reading, but the company is now back on track.

For more details on Jackson Brothers products, contact Mainline Electronics, Dept EPE, PO Box 235, Leicester LE2 9SH, UK.

Tel: +44 (0) 116-277-7648

Fax: +44 (0) 116-247-7551

E-mail: sales@mainlinegroup.co.uk

Go to next section

Readout

John Becker ***addresses some of the general points readers have raised. Have you anything interesting to say? Email us at editor@epemag.com!***

WIN A DIGITAL MULTIMETER

A 3 1/2 digit pocket-sized LCD multimeter, which measures AC and DC voltage, DC current, and resistance. It can also test diodes and bipolar transistors. Every month we will give a Digital Multimeter to the author of the best *Readout* letter.

* LETTER OF THE MONTH *

INGENIOUS!

Dear EPE,

On obtaining EPE Nov '99, I wasted no time in trying out the One Volt LED from Ingenuity Unlimited. Instead of winding the inductor myself, I salvaged a toroidal mains filter common-mode choke. I am a self-employed computer monitor repairer, I have plenty lying around. The one I picked was because it was simply the easiest to get at on the pile of scrap chassis, and just happened to have a pair of windings of 23 turns each – near enough!

As ZTX650s are not common in my line of work, I picked a device certain to out-perform, a BD433. Resistor R1 was made up from a 2k2 resistor and 50k preset, so that I could have a twiddle and observe the result – had you noticed that if you pulse-drive a red LED hard enough it produces orange light?

The blocking oscillator produced excellent results, I couldn't resist experimenting! The LED will light either way round if connected across the collector winding, and produces brighter light than across the transistor collector/emitter as shown. However, if you really want to produce some light, put the LED across R1 with the cathode to TR1 base and the anode to the top tap of the inductor, although a single LED gets rather hot, and isn't likely to last long. Five or six LEDs in parallel seem to work well, without noticeable temperature rise.

The value of R1 doesn't seem to make much difference, I suspect that the flyback phase of the oscillation cycle is using the LED leakage to feed negative regeneration to the transistor's base, which is not a good idea! An ordinary diode connected in inverse parallel with the LEDs is required to damp the reverse voltage across them. This makes no difference to the light intensity.

As you may have gathered, this topic is of considerable interest to me. How about a *Circuit Surgery* special on calculating windings and toroid core dimensions, with some guidance on how to estimated energy transfer and how to determine the frequency of operation?

I. Field
Letchworth, Herts, UK

That's what we like to hear – readers taking ideas from published designs and modifying them for their own purposes or whims. More power to you all!

We've passed your CS suggestion to our Circuit Surgeon, Alan W, who is at the cutting-edge, so to speak!

PIC CHANCE

Dear EPE,

Referring to your Nov '99 Editorial, I would like to share my views on the topic of "Give PICS a Chance".

Here in South Africa, there are so many people who would like to play with or learn the PIC microcontroller that I am often inundated with requests for help on the subject. As I am among the top PIC enthusiasts in SA (or so everyone reckons), I know how versatile these devices are, and believe that your magazine fills a need in PIC. I know there are people who are "PIC Ignorant" but they are normally converted the day they try to do some digital controller of any sort, and end up with boards of TTL chips. So please, keep up the PIC projects, as many students here use them as the basis for university and college assignments.

About General Instruments selling them since 1982, this is indeed true, as in 1995 I repaired a module coming from an AEG washing machine, 10 years old, with a PIC1654 (TTL version). I even believe that General Instruments used the RISC PIC core in other products such as the SP0256 Speech Synthesizer (remember this

one? – the *EE Speech Synthesizer Project* for the BBC Micro in 1983) and maybe the AY-3-8910 programmable sound generator, and also in some GI chips in the Interface One for the Sinclair ZX Spectrum. Very, very interesting.

Please keep up the good work, your magazine is great, and the only one that bothers to provide any PIC source code and/or flow diagrams.

Jason Mitchell
Gauteng, South Africa
via the Net

We know full well that the great majority of our readers have an interested in PIC related designs etc. It is not due to some whim of mine that Readout *pages have a lot of letters concerning PICs and other programming matters, it's because they are the subjects that most readers write to us about. We get far, far more letters than ever reach these pages and when writing on other subjects (not necessarily suitable as* Readout *matters), readers often also offer comments on what we are publishing.*

Yes, the SP0256 device we remember well, and I too have played around with it, it was sadly missed when it became obsolete.

ENVELOPING TEACH-IN

First the exclamation, and then the simple explanation:

Big Al . . . thanks for your help, I have got the Teach-In 2000 now and it is MOST wonderful . . . er . . . I never knew that a directory was the same as a folder ... I always baulked at the word "directory" as I always thought this to be synonymous with "registry" and other such things that I have tried to steer clear of.

Ian Gill
via the Net

Well, that's the satisfactory conclusion to an E-mail discussion between Ian and our Online Editor Alan. Ian had queried with Alan what I had meant in my TEACHIN.TXT software file when I referred to "creating a directory". It never occurred to me that anyone who had a computer would not know what a directory is. Alan points out that "newer Windows 98 users will use the word folder".

Thanks Ian for the praise, thanks Alan for helping Ian (and other '98 fans as well perhaps).

But Ian, why should you be afraid of "registry"? Or are you being humorous and making an indirect reference to Marriage (as in "Registrar of")?

PICMAN

Dear EPE,

As a PICman of long standing I would like to contribute my two cents worth to the PIC or not to PIC debate.

I first found out about PICs way back in '89 I think, when CMOS PICs first became available in the UK. Of course they were the 16C5X series, where previously only NMOS versions had been available, which were mask programmed and therefore not suitable for small scale use. Having obtained and studied the data sheet and later the data book my thoughts were "Microchip are onto a winner here". And I was right, they must be the most popular microcontroller on the market.

Wanting to get my hands on a PIC, I built a simple parallel port programmer. But I didn't have an assembler, so designed a set of macros for the PIC instruction set and used the macros to assemble my PIC programs into PIC code. Simple! Who says you can't make do with what you've got?

The problem with PICs is that they are so darned useful (and cheap). Designing software is not really any different to doing it in hardware, except software comes free after you have spent the time writing it, and hardware costs hard earned cash, so software should be a part of electronics and not a separate subject. After all you are just designing the logic in software instead of wiring up ICs.

To illustrate the point of using PICs, I spent a few hours one evening re-designing the Ginormous Display (Dec '99) without using any kind of microprocessor. The result was a circuit considerably more complex, what with a UART, Baud rate generator, 4-bit comparator, data latch, 7-segment decoder/driver, plus glue logic. And the expense of it all!

I would also like to say a few words concerning the PIC Micro-Probe (Dec '99). I have no doubt it is a useful tool, but it isn't the be all and end all of debugging. In most of my programming errors, the problem is not that the program loses its way, but algorithms not handling the data correctly, or protocol problems between different sections of code. All caused, of course, by brain failure when writing the code.

My preferred method of debugging is to use the simulator in MPLAB, not to simulate the

whole program but to test sections of it to ensure it is working correctly. MPLAB is very easy to use once you get the hang of it, not as easy to learn as *Toolkit* but much better for writing and debugging code. I would suggest anyone who wants to write their own code should give MPLAB a try.

Peter Hemsley
Somercotes, Alfreton, Derbys
via the Net

I admire your initiative and agree with your comments.

As a further comment, no-one objects to "yet another opamp project" or one that uses any manner of other "standard" devices. To my mind, PICs should be equally regarded as "standard". It's not as though readers have to program them themselves, all our PIC-based projects can have their PICs bought as pre-programmed devices which simply plug straight in, as does any other dual-in-line IC.

TEACH-IN DISPLAY

Dear EPE,

Further to the Teach-In 2000 "hieroglyphics" question raised in Readout Jan '00: When my screen printed garbage, I rang John Becker who helpfully suggested that the problem may be something to do with the code-page in use by the system. After some experimenting I came up with the following solution:

In the directory where you installed the Teach-In 2000 software, create a batch file called MENU.BAT with the following commands in the file:

```
mode con codepage prepare=((850) C:\ WINDOWS\ COMMAND\ ega.cpi)
mode con codepage select=850
mode con codepage prepare=((437) C:\ WINDOWS\ COMMAND\ ega2.cpi)
mode con codepage select=437
ty2kmenu.exe
```

make sure the file MENU.BAT is now saved to disk.

Whenever you want to run the Teach-In 2000 software run the batch file you just created, i.e. MENU.BAT.

Alternatively you could create a shortcut to this file on your desktop if you are using Windows 95 or Windows 98.

Hope this helps out others who are having the same problems with the software.

Gordon Murgatroyd
via the Net

So I thanked Gordon for the useful suggestion, but expressed my concern that the user's system would be changed and not be re-instated when Teach-In is exited. Gordon came back with the following:

Yes, I do have a solution. The user needs to add two lines similar to the above mode con lines, which are found in the AUTOEXEC.BAT file on the user's C: drive and could be copied from AUTOEXEC.BAT using the copy and paste commands.

The following are those copied verbatim from my AUTOEXEC.BAT file:

```
mode con codepage prepare=((850) C:\ WINDOWS\ COMMAND\ ega.cpi)
mode con codepage select=850
```

I've tried the above technique and it appears to work on my system and leave it in the same state as when the system booted. Of course, this will only work when the system in question has an AUTOEXEC.BAT file since I believe this is not absolutely required for Windows 95/98.

The only ideal solution for today's modern systems would be to use a programming environment more suited to Windows such as Visual Basic or, better still, Borland/Inprise Delphi, for the creation of the Teach-In software.

The batch file solution is not ideal, I'll be the first to admit that, but it works for me.

Since Gordon replied I've done further tests on my machines (and I've recently acquired two more, including a Win98 Dell and Win NT Dell). Gordon's solution works on some, but not all. There is the nagging suspicion, though, that the problem is more likely to occur with machines that have been upgraded. Those of mine which are purely Win 3.1, or Win 95 or Win 98 are perfectly happy with QBasic and with the old EasyPC I referred to last month. It's the machines that started off as 3.1 but have been upgraded to 95 on which the "hieroglyphs" can be caused to occur, either in QBasic or in EasyPC, but never in both for the same country code settings.

I have not yet been able to reproduce the problem in the purely Win 95 and Win 98 machines. The Win 98 machine does not recognize codepage commands, nor does one Win 95 machine at EPE HQ. (The

Win NT I've not been able to access yet – it came from my wife's employers when they upgraded to later machines and requires an entry password, which has still to be advised!)

I'm hoping for more reader feedback on this curious hieroglyphs situation.

PIRATE-PROOF CDs

Dear EPE,

I've just decided to drop my fortnightly computer magazine in favor of EPE. Yours has a lot more interesting stuff in it. I've been following the series on Oscillators (Jul-Dec '99) and, as getting a copy off the counter was not always possible, a subscription was the only choice.

The news item on page 874 of the Nov '99 issue, where the company C-Dilla are planning to launch a copy protection system, is in itself no problem for me. However, if the report is correct and I will not be able to play music CDs on my PC, I shall be more than a little upset.

I purchased a high-performance multi-media PC almost a year ago, and took great pains to ensure that one of its many capabilities was to play stereo CDs to delight my ears while I used it to perform other tasks. Some CDs even have a computer track included, such as some Classic FM cover disks.

My system is perfectly capable of copying CDs I believe, but as I don't play any of the fancy games, and my son believes that his Amega is a better computer anyway, there isn't even the temptation. The copy facility does have its uses though. A friend is a musician who plays his own compositions on a "Chapman Stick", and gets them professionally recorded on a CD master. My machine then provides him with all the copies he needs to sell. For a single instrument, it sounds like four John Williams and just as professional.

The piracy of "pop" music is probably extensive, and the urge to stem it is understandable. But I believe that technology is its own worst enemy, much like a knife blade, which is all cutting edge and no handle. There will always be someone who finds a way to misuse it.

In the meantime, I do not accept clumsy attempts to protect "intellectual property" which prevent me from being enraptured by Clannad while reading through some of the banal E-mail I get.

An interesting thought here. If they don't bother to warn the purchaser that the CD won't work on the PC's hi-fi system and he/she takes it home and plugs it in, hoping to hear their favorite blasting from the speakers, and all he/she gets is a "disc faulty" message and the CD rejected, will they be able to get their money back? Can they complain to the trading standards that the CD was not fit for the purpose it was purchased?

Arthur Lawrance
Poole, Dorset

Anyone care to add to this potentially interesting debate?

PCB PRODUCTION

Dear EPE,

I hope this may help N. Dyson (Sep '99 Readout) regarding PCB production: Whilst at college, the design package I preferred printed from a dot-matrix in either 1:1 scale for preview purposes or 2:1 for production quality. The latter meant reducing by 50% using a photocopier and at the same time transferring to acetate. This worked well providing the copy quality was good. It was required at times to double the design back to back to block the UV light during exposure, although with some adjustment to the copier settings, one copy could be used. This may save the cost of special ink or a new printer.

Also, I would like to congratulate you on the merger with ETI. I had concerns that the competition to produce designs for all standards of enthusiast would be reduced with less competition, and that you might go completely into PIC design, which I feared you were nearing. I had hoped that you would introduce more stripboard designs and projects using more components rather than a programmed IC. The starter projects are excellent examples, and long may they continue.

Martin Smith
Banff, Scotland

Points well noted, Martin. Thank you.

In my published reply to N. Dyson, I said that my new ink-jet printer produced excellent acetate images for use with UV exposure onto photosensitive PCB material. I now have to add a caution to that comment. Having run out of the original Epson ink supplied with the printer, I made the mistake of replacing it with a much cheaper brand, to my regret!

This ink slowly spread out across the acetate, refusing to dry adequately (although images on paper were perfect). The results were terrible and required a great deal of touch-up work on the final exposed and etched board to make them

usable. I have now reverted to Epson's own ink!

Yes, many people find that stripboard provides a good constructional medium for one-offs. However, I prefer to use PCBs, not only because I have the facilities, but also because I feel that the chances of making a constructional error are much reduced, all the connections being pre-ordained!

MORE INGENUITY

Dear EPE,

I have enjoyed reading EPE for a considerable time, though my knowledge of electronics is very limited. Many people told me that modern electronics with its complexity was becoming beyond the amateur. However, I became interested in the possibility of using various simple devices. The first unit I built was an auto-dialler, and a last number redial on the handset.

This worked well so I linked it to a PIR sensor as a burglar alarm. This has one advantage over most auto-diallers in that when activated you can listen in. I also designed a simple unit for my camera, with PIR for taking wild-life photographs. I had not been able to purchase any of the above units ready-made at a reasonable cost.

Roy Hancock
Witheridge, Tiverton, Devon

Yes, Roy, there is much that can be achieved by hobbyist electronics enthusiasts without becoming involved in high-tech designs and control systems. We applaud your resistance to those who said otherwise, and commend you on your ingenuity.

We must, though, caution readers about attempting to connect non-approved electronic equipment to the public service telephone network. Doing so is against the law. We assume that Roy used his auto-dialler with a private telephone system that was not subject to legal requirements.

EPE IN ZIMBABWE

Dear EPE,

In his letter (Readout Sep '99), Mr Cornish, who for an unknown time was a resident here in Zimbabwe, said he had problems in getting copies of EPE due to restrictions imposed by the Zimbabwean Government. It's now four years since I started reading your magazine. I live 290km away from the capital city Harare but am getting my copy of EPE on time from a general dealer shop, which is supplied by a distribution company based in Harare. It is also sold by street newspaper vendors and in bookshops. There are no Government restrictions on EPE.

Innocent Mutasa
Masvingo, Zimbabwe

Thank you for the reassurance and your lengthy letter, of which the above is a brief edited extract. We hope you will understand that we cannot publish your political comments in EPE, even though you obviously feel passionately about your country.

Go to next section

Shop Talk

with DAVID BARRINGTON

Some Component Suppliers for EPE Online Constructional Articles

Antex
Web: **www.antex.co.uk**

CPC Preston (UK)
Tel: +44 (0) 1772-654455

EPE Online Store and Library
Web: **www.epemag.com**

Electromail (UK)
Tel: +44 (0) 1536-204555

ESR (UK)
Tel: +44 (0) 191-2514363
Fax: +44 (0) 191-2522296
Email: **sales@esr.co.uk**
Web: **www.esr.co.uk**

Farnell (UK)
Tel: +44 (0) 113-263-6311
Web: **www.farnell.com**

Gothic Crellon (UK)
Tel: +44 (0) 1743-788878

Greenweld (UK)
Fax: +44 (0) 1992-613020
Email: **greenweld@aol.com**
Web: **www.greenweld.co.uk**

Maplin (UK)
Web: **www.maplin.co.uk**

Magenta Electronics (UK)
Tel: +44 (0) 1283-565435
Web: **www.magenta2000.co.uk**

Microchip
Web: **www.microchip.com**

Rapid Electronics (UK)
Tel: +44 (0) 1206-751166

RF Solutions (UK)
Tel: +44 (0) 1273-488880
Web: **www.rfsolution.co.uk**

RS (Radio Spares) (UK)
Web: **www.rswww.com**

PICVideo Cleaner

As the design for the *Video Cleaner* project is based around a printed circuit board (PCB), the choice of components will need to be selected to fit on the PCB. Also, a couple of the semiconductors are a bit special and not readily available.

Dealing with the 3VA mains transformer first. This was purchased from Farnell (code 141-471). You could use a different transformer provided you can "hardwire" it to the PCB. *(Also, as was noted in the article, please remember that this transformer was selected based on the project being used with a UK 240V 50Hz power supply – see the article for more details.)*

Like most of the "specials" for this project, the plastic box (code 223-440) and metal socket support brackets (146-318) also came from the above company. The right-angle SCART sockets should be available from most component suppliers.

Turning to the semiconductors, Farnell supplied the LM1881 video sync separator (code 410-536), the AD810 low-power video amp (code 295-127) and the 1KAB10E 1·2A 40V bridge rectifier (code 371-208). Note the bridge rectifier is sold in packs of five.

The PIC used in this project must be the 10MHz version. For those who would like a ready-programmed PIC, one is available from Magenta Electronics for the inclusive price of 5.90 UK Pounds (overseas readers add 1 UK Pound for postage). Our understanding is that they will be using the F84 which is pin compatible with the F83. For those who wish to program their own PICs, the software is available for Free download from the *EPE Online Library* at **www.epemag.com**

The printed circuit board is available from the *EPE Online Store* (code 7000251) at **www.epemag.com**

Find It

Most of the components needed to construct the *Find It* project should be readily available parts. The specified LED used in the model is a "high brightness" type, which was found to give better results than the standard variety. The high brightness types are now common shelf lines, however, watch out, some LEDs may have a narrow viewing angle which could cause "off-center" viewing problems.

You may have to search through the various resistor ranges to track down the high value ones that are needed to make up the two series resistors that form the "frequency" resistor R5. It looks as though the author found his amongst the 0·6W and 1W (high voltage) metal film ranges. If difficulties should arise finding these, try

Maplin (codes M10M and V4M7).

Most component suppliers should be able to offer a suitable miniature type light dependent resistor. The one in the model came from the above company, code AZ83E. Readers who have difficulty obtaining the miniature LDR could use the old favorite ORP12 type, but a larger case may be needed. Also, resistor R1 may need to be reduced in value as explained in the text.

The micropower 7611 opamp has been used in past projects and should be obtainable from most component suppliers. Finally, the small printed circuit board is available from the EPE Online Store (code 7000252) at **www.epemag.com**

Voltage Monitor

The LM393N 8-pin dual comparator called for in the *Voltage Monitor*, this month's "starter project", appears to be stocked by most component suppliers. however, the voltage reference chip could cause some concern.

The voltage reference type ICL8069 is produced in metal cased and plastic encapsulated versions. Although the prototype model shows the metal can version, the plastic package seems to be the one most widely stocked, so we have included the pinout details (top views) for both versions in the article. If readers do experience any problems sourcing the 8069 locally, the plastic version is listed by Maplin, code YH39N.The small stripboard will need to be cut to size from a larger standard piece. ***Finally, it is most important that an in-line fuse/holder is included in the positive supply lead if the unit is to be used in a car, caravan, boat etc.***

Easy-Typists Tape Controller

Not too much can go wrong when ordering parts for the *Easy-Typist Tape Controller* project, except perhaps locating the 8-pin voltage converter IC. Of course, you are left on your own regarding selection of a microcassette machine.

We can only find the SI7660 voltage converter listed by Maplin, code YY75S. They also supplied the little sprung, momentary action (biased-off), footswitch pedal, code DU99H.

Once again, you will have to cut a standard piece of stripboard down to size for this project.

Teach-In 2000 (Part 4)

A small "interlink" printed circuit board, for the *Computer Interface – Experimental 4* exercise, has been added to the components for this month's installment of *Teach-In 2000* series. This PCB is available from the *EPE Online Store* (code 7000253) at **www.epemag.com**

For details of special *Teach-In component* packs readers should contact:

ESR Electronic Components – Hardware/Tools and Components Pack.

Magenta Electronics – Multimeter and components, Kit 879.

FML Electronics (Tel +44 (0) 1677-425840) – Basic component sets.

N. R. Bardwell (Tel +44 (0) 114 255-2886) – Digital Multimeter special offer.

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